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AND A RECORD OF PROGRESS

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Episodes in Early Telephone History

Extracts from an address by John J. Carty, Vice-President of the American Telephone and Telegraph Company, before the Chamber of Commerce of Boston, Mass., March 11, 1926

I DO not know how to express the emotions that I feel coming back here to Boston under such splendid auspices to address the Chamber of Commerce—coming back to the city of my youth which I love so well, and coming back to the scenes of many historic achievements dating back long before the days of the Revolution, and including among them the invention of the telephone. The chapter of the invention of the telephone—in fact, a great volume concerning the invention of the telephone—will constitute forever a memorable and a glorious chapter in the history of Boston, for the telephone is a Boston institution. To be sure, the inventor was born in Scotland, but he became an American citizen. He was a great man—Alexander Graham Bell. He was my friend and my colleague. As long as I live I shall do him honor.

He came with his parents to Canada and soon after came to Boston. It was at Boston that the telephone was invented by him. It was here that Bell received the scientific support and encouragement which he needed. It was here from your predecessors among the great merchants and financiers of Boston that he received the necessary encouragement and financial help.

At an early stage Bell went to England and made a masterful appeal for help. He wrote a wonderful letter which constitutes a prophetic document today, a prophecy that has been fulfilled. But he appealed to deaf ears in England and there he got no support. He came back here to Boston, and here he got support.

Bell was a professor at the Boston University. That is a significant thing, in a special way tying the invention up to the name of Boston. Although his work was not done in the university or as a part of its work, yet it was done by one of its faculty.

Bell had no money. University professors in those days were paid more poorly even than today. He was a professor of vocal physiology, whatever that may mean now. We do know that he paid great attention to elocution and was the foe of that method of teaching the deaf to communicate by signs made with the fingers. He was an advocate of visible speech. He studied this, and he inherited a liking for it, and obtained a knowledge of it from his father. His studies in this direction brought him in contact with Gardiner Hubbard, who was interested in such matters. Gardiner Hubbard was a Boston lawyer. His studies also brought him in contact with a Boston merchant, Thomas Sanders, one of your predecessors. Sanders had his home in Salem. Sanders and Hubbard together had limited means, but they had confidence in Bell and his prophecies and his inventions, and they helped him.

Bell was working on an harmonic telegraph whereby a number of messages might be sent over a wire simultaneously, using a method of tuning. Tuning, we now

know, even boys do with the radio sets. This telegraph invention seemed as though it might bring in some money, sufficient to let Bell work upon the most visionary of all ideas—the transmission of speech by electricity, or as they used to call it in those days, transmission of speech by telegraph.

The Electric Speaking Telephone

The word 'telephone' was in use—you will find it in the old dictionaries—but not in the sense that we now use it, so that you will find in the old literature the early expression describing the telephone was 'the electric speaking telephone.' We had acoustic telephones before that, and they were speaking telephones, but they were not electric. We had also a thing called a telephone that would send a note or a noise like a buzzer. That was electric, but it could not speak. So we had an electric telephone, and we had a speaking telephone, but we did not have an electric speaking telephone. It remained for Alexander Graham Bell to reveal to mankind the principle upon which the successful electric speaking telephone should be constructed.

He labored upon this subject and finally evolved his theory, but years of labor and experimentation with very inadequate means, conducted in this very city, elapsed before he was successful. So fifty years ago yesterday, Bell finally demonstrated that his theory would work. Right here in this city, at 5 Exeter Place, on March 10, 1876, Professor Bell spoke into an instrument over a wire less than fifty feet long, extending to another room in that building. Bell said over the wire, 'Come here, Mr. Watson, I want you.' The transmission was very faint, but Watson heard distinctly every word. Young Watson had listened for many weary months for words, and certainly he was ready for them when they came.

Bell then, as always, was a masterful elocutionist, and this first sentence, 'Mr. Watson, come here, I want

you' has become historic and the work which Dr. Bell did rendered his name immortal. Nobody else can do this for the first time. Bell's invention had to do with the transmission of speech. It is not like some other inventions, which may disappear with the vagaries of fashion or with changes in the habits of our people, for as long as men can speak and as long as men can hear you may be sure they will employ the telephone. It will be an improved form, but still the principle of Bell will endure.

Watson First to Hear

Boston, therefore, has produced an inventor whose name will be recorded for all time among the immortals. He was the first to speak over the telephone, and Watson was the first to hear. Watson was a young boy who lived in Salem and worked at the shop of Charles Williams at 109 Court street. Watson with his own hands made the first instrument and he ran the first wire and he heard the first words. There never can be another Watson. There can be only one first. He was the first human being ever to hear words transmitted by telephone—by the electric speaking telephone.

Now, to show how rapidly these things happen: Looking ahead fifty years seems a long time, but only this morning I got a telegram from Mr. Watson, who is a little over seventy, hale and hearty, enjoying himself on the sands and in the sun in Florida, asking me to express to the members of the Chamber his great regret that he could not be here to assist on this occasion which I think we must regard as one of the occasions when a great achievement of Boston men is being sung.

The Telephone at the Centennial Exposition

When the telephone was invented by Bell and when the first sentence was transmitted in this city, it was taken to Philadelphia in 1876 and there exhibited at

the Centennial. It received an award of merit. Dom Pedro was there, the Emperor of Brazil, and he happened to be a friend of Bell and spoke to him, and it was that which drew attention to the telephone. Then they looked at it with interest and Bell got an award. I read a two-volume book by General Walker, an official report of the Centennial, and I looked through it in vain to find a word about the telephone. I have looked through many other volumes about the Centennial of 1876. There was much about the Corliss engine, and you will be surprised to know that there was much about the printing telegraph; there were threshing machines and Yankee notions of all kinds which received page after page of text and many full-page illustrations, but not a word about the telephone.

It is difficult for you now to appreciate the courage and the vision of these great merchants of Boston who undertook to back Bell. Nobody would put a telephone in the house. It was a nuisance. Nobody wanted it in a business office. It was difficult to get anybody to invest a dollar in the telephone business. Notwithstanding that, with that fine old Puritan spirit which settled and developed this city, these men went forward with confidence and with faith and against all obstacles. They finally achieved.

The first actual outdoor line that was used was part of an experiment tried one night over a telegraph line from the Walworth Manufacturing Company in Boston to their works in Cambridge. The first actual line permanently installed was a private line from the factory of Charles Williams to his house in Somerville. Things went on and a line was extended to Salem. It was a long line. Indeed it was so long that it was very difficult ever to get a message through. Lawrence and Lowell came into the system and finally Providence and Worcester and then New York. All of these things meant a struggle. Finally we reached Chicago, and then Omaha and then Denver and finally San Francisco.

THE WIRES SPAN THE CONTINENT

One of the greatest achievements of the telephone was when we talked from Boston to San Francisco in 1915—January 25, 1915. It seemed to the telephone pioneers that until we could span the continent we had not done our job. It was their ideal that anybody in the United States could talk to anybody else in the United States within a reasonable time. On that great day in 1915, we had a very remarkable development, and I hope you will pardon me on this historic occasion, if I call it to your minds.

Our President, Mr. Vail, had received an injury to his knee and was at Jekyl Island down on the coast of Georgia, Mr. Watson was in San Francisco, Dr. Bell was in New York and Major Higginson was at Boston. Many others were present. We had also, at Washington, the White House connected. A great many historic things happened that day. One which affected me in a personal way was this: As a youngster here I often made telephone connections connecting Mr. Vail with one place or another in this neighborhood, but on that day—I have never mentioned this before—I cannot tell you the thrill I felt when I connected President Wilson at Washington with Mr. Vail at Jekyl Island, and when I heard the President of the United States congratulate Mr. Vail, when I heard him congratulate and talk with Bell at New York and with Watson at San Francisco. Then my thoughts went back to the old Boston days when it was difficult to talk across the street.

I will not weary you with a list of what has been done—so much of it is fresh in your minds—but I would perhaps be derelict, particularly as I understand I am talking to a radio audience, if I did not say something about radio.

Bell's Invention for Projecting Sound by Light

In the paper this morning I find this headline: 'Tech Instructor Talks Over Light Ray, Where Bell Failed.'

> "Two striking revelations became known yesterday concerning the telephone and its inventor, Alexander Graham Bell. More than forty-seven years ago Bell attempted to talk over a ray of light. Last Thursday an instructor in physics at the Massachusetts Institute of Technology succeeded."

Then the reporter quotes my good friend Eustis Hubbard as testifying that he was present at Washington in 1878 when Bell tried and failed. It is true that in 1878 Bell tried and did fail and that Mr. Hubbard witnessed his failure. But what is not contained in the article I will now tell you about. There was an article in the Popular Science Monthly for October, 1880—I ask the reporter who wrote today's article to read the one by Alexander Graham Bell, 'On the Projection of Sound by Light'—and please note the date, 1880. It is interesting to note also that this article refers to a lecture that was delivered on this subject by Professor Bell before the American Association for the Advancement of Science, and appropriately enough the meeting was held in the Massachusetts Institute of Technology.

What did Bell say, among other things, on that day? After describing his invention for talking over a ray of light, he says:

> "We can thus, without a conducting wire, as in electric telephony, speak from station to station wherever we can project a beam of light. We have not had opportunity of testing the limit to which this telephonic influence can be extended, but we have spoken to and from points 213 meters apart, and there seems to be no reason to doubt that the result will be obtained at whatever distance a beam of light can be flashed from one observer to another."

Bell says further:

> "Dr. Tainter"—that was his assistant—"operated the transmitting instrument which was placed on the top of Franklin Schoolhouse in Washington, and the sensitive receiver was arranged in one of the windows of my laboratory, 1325 L street, at a distance of 213 meters. Upon placing my telephone to the ear, I heard distinctly from the illuminated receiver the words, 'Mr. Bell, if you hear what I say come to the window and wave your hat.' "

I think that evidence is explicit enough to satisfy even such an exacting lawyer as your president.

Bell applied for a patent for this wonderful invention and he received it. The libraries of all of our scientific institutions contain a full record of this, and so do all collections of patents. So if ever there was anything well established, it is that the first talk over a ray of light did not occur on the fiftieth anniversary of the telephone, but it did occur about 1880, was duly patented, and Bell among well-informed scientists has long been known and recognized all over the world as the author of that very great invention.

I cannot leave that point without mentioning to you a letter that I received from Mrs. Bell shortly after the death of her husband. Bell, having demonstrated this principle, and his work having been repeated by others, including myself, many, many years ago—Bell did not follow it up. His wife wrote me, saying that, 'I verily believe that the reason Dr. Bell did not follow up his invention of the photophone'—or radiophone as it became afterward—'the reason he did not follow that up and the reason he took up aviation instead was that I could not hear what went on over the radiophone'—for she was deaf—'but that I could see the flying machine.'

It was a very touching letter and reminds me of what happened on his great day of triumph when Bell talked across the continent to Washington and when

he received the congratulations of the Chief Magistrate of our Nation. Mrs. Bell was there and Bell, with a poignant sadness, looking towards his wife, said to me, "And to think that she has never heard through the telephone."

So to Dr. Alexander Graham Bell goes the credit for being the first man to devise a wireless telephone and successfully to talk through it. To be sure, the transmitting apparatus was not that which is now used, nor indeed, was the receiving apparatus that which is now used. But it is very interesting to remember that the medium employed was the same, electromagnetic waves transmitted through space.

Light waves differ from the radio waves that are now carrying my voice largely, if not solely, in being very, very much shorter. So that we must give to Bell the credit for being the first one to devise a radio telephone.

Communications by Radio

Now, speaking about radio and long distance talk, after we had successfully conquered this continent telephonically speaking, we sought, as did these early merchants who sent out their agents to all parts of the world, actuated by that same old Boston spirit, to transmit the voice to the uttermost ends of the earth, and it was our desire and our determination that this should be done by America and not by some other nation. There was a patriotic pride in it.

First we had it studied by our physicists, who advised us that theoretically it was not contrary to the known law of physics that we should be able to talk through the ether. First we talked from Montauk Point to Wilmington, Delaware. All of this was a struggle. Next we talked from Montauk Point to St. Simons Island off the southern coast of the United States.

That gave us confidence that our principle was sound and that it was safe to try to talk across the Atlantic.

The war was on at that time, although we had not yet entered it, and we could not build towers there or here. With the permission of the Navy we utilized the towers at Arlington and erected our own apparatus there, and the Navy obtained for us permission from the French Government to send our engineers to France to experiment. I sent an expedition at the same time also to Hawaii, one to San Francisco, one to San Diego and one to the Isthmus of Panama, all ready to pick up the messages which we would send. We started on the fourth of July, 1915, I think it was, and, of course, we got no results. We kept it up until the latter part of September, when Mr. Vail in New York talked to me in San Francisco over the radio and I talked back by wire. The next day Arlington was heard by the engineer whom I had sent to Hawaii and he cabled back what was said. A few days after, when static was absent, Hawaii heard with the receiver three feet away from the ear.

Please note the early dates of these things, all of you who are so interested in the history of radio. San Diego made its report and so did the Isthmus of Panama. We were heard at all these places. But there was a certain romance about talking across the Atlantic, perhaps because of the old Mayflower spirit. But, at any rate, we failed in our first attempt to talk across the Atlantic. At last, in October, when the static disappeared, we succeeded for the first time in transmitting the human voice across the Atlantic. It was heard there by the United States Naval Attaché, by the two engineers whom I had sent out and by General Ferrié of the French Army and by other officials. It was duly attested and the record was secured and nailed to the mast for America.

But, of course, the talking in this manner was at times difficult; at other times impossible. The war interrupted our experiments, but they were resumed after the war, and in January, 1923, using the tower of the Radio Corporation of America, three of my col-

leagues and myself talked one night to a group in London at a predetermined hour. We talked for two hours and we were heard in London at that date as plainly as you now hear me. In fact, at that time the British had no apparatus with which to talk back, so it was arranged that to our office the end of an Atlantic cable was brought so that the British could in replying at that time use the good, old fashioned, conservative cable, and we got our messages back by telegraph in that way.

The Future of the Telephone

Now, as if to celebrate the fiftieth anniversary of the telephone—the Bell patent was dated March 7, 1876—on March 7, 1926, there was the first two-way conversation held across the Atlantic Ocean between the telephone office in New York and the telephone office in London. A group of newspapermen talked to each other and the talking was just as clear and distinct as any you ever had an opportunity to hear.

Well, that opens up for us very great possibilities. But there is an old saying that nothing great is easy, and while all these things were done we have a long way to go before Boston in New England will hold a telephonic reunion with Boston in old England. But that day is coming when the descendants of these Boston merchants can talk to all parts of the world where in the old days their sailing ships went and where they had their representatives and where you now have your representatives, and where I hope they will increase in numbers—we have a long way to go before telephony on a practical commercial scale to England and the rest of the world will be accomplished.

One of the difficulties with this transoceanic radio is the static, which is enormously increased when the necessary amplification for such great distances is applied. The static is more prevalent in the daytime than in the night or, at any rate, is more prevalent in

the summertime than in the winter. The transmission, aside from static, is very much better at night than in the daytime, and during the period of twilight special difficulties arise. But aside from all that, the expense of such a service it is impossible now to foretell, and it remains to be seen upon what scale and how frequently, at what time of day, what time of the night, and at what expense practical commercial transmission can take place. But at any rate, the achievement has been completed on the fiftieth anniversary. Talking has gone on most successfully between old England and, I may say, New England, because the receiving station where this talking came was in Houlton, Maine, and the wire carried the words to New York.

Improvement in Toll Service Through Combined Line and Recording Method

THE further improvement of telephone service is always a matter of first importance in the Bell System, and a large amount of effort is continuously directed to that end. Activity along this line aims not only toward obtaining the best possible results from the existing methods and practices, but also to the development of improved plans.

The remarkable growth in telephones and in telephone traffic is continuously presenting new problems and emphasizing the importance of using methods which give the most satisfactory service results with simplicity and efficiency in operation. It is more or less obvious that the handling of upwards of 70,000,000 telephone calls daily and the interconnecting of some 12,000,000 owned and nearly 5,000,000 connecting company stations presents many problems which would furnish material for a description of some interest.

One of the best examples of the progress being made in method development work is the so-called combined line and recording plan of toll operation. In order that there may be a clear understanding as to just how this new plan fits in with the general toll operations, it will be well to consider briefly the general characteristics of toll traffic, the general methods by which it has been handled, and the results that have been obtained.

When speaking of toll traffic, most people think first of toll board service. It is true that a large part of the toll revenue is derived from calls handled at toll boards, but counting the toll calls, two-thirds are completed by local operators and this proportion is constantly

increasing. There were nearly 800,000,000 toll calls handled in 1925 and they were divided as follows:

	Yearly Calls	Average Speed of Service
Handled by local operators	510,000,000	40 seconds
Handled at two-number toll boards	40,000,000	75 "
Handled at toll boards	240,000,000	7 minutes
	790,000,000	2.6 minutes

The fastest and most satisfactory toll service is given when the local operator first receiving the call from the subscriber completes it herself. The large volume of short haul traffic around the large metropolitan centers lends itself particularly well to this kind of handling, and the "A-B" plan was first worked out to meet these conditions. It has been possible, however, to develop means for extending the advantages of this type of toll service to the smaller places and to the more scattered traffic, and there has been a steady increase in the proportion of toll calls handled at the local boards. In 1915, 45 per cent. of all toll calls were handled at local boards. In 1925, the percentage had increased to 65 and the outlook is that by 1930 it will be 70 per cent.

It is probably not generally appreciated that such a high proportion of all toll calls are now being handled by local operators or by the closely allied two-number method with an average speed of service of less than one minute, which approximates the service on local trunked connections. This rapid handling of 70 per cent. of the business makes the average speed on all toll calls 2.6 minutes, as brought out in the table, which compares with the toll board speed of 7 minutes. When we speak of speed of service we refer to the length of time required to give the subscriber the desired connection or definite information that the call cannot be completed immediately due to the called subscriber's line being busy, to the fact that the person desired is not available, or to similar conditions.

There are, however, definite limitations to handling toll calls at the local boards. For example, local operators cannot ordinarily handle particular person calls nor calls on which the number of the called subscriber is not furnished. Toll calls over longer distances present more difficult problems in securing satisfactory transmission than do local calls, and it would be found difficult and expensive to meet these requirements at the local switchboards. Furthermore, in the handling of the longer haul calls, it is desirable to obtain more efficient use of the expensive toll line plant involved than appears possible with local operation without reaction on local service.

For such reasons, therefore, it is necessary that the medium and long haul toll traffic be handled at toll boards and it is to the bulk of this traffic that the advantages of the new combined line and recording plan will apply.

The Combined Line and Recording Plan

Briefly, the combined line and recording plan provides for the handling of the toll call by the operator to whom the subscriber gives his request for toll service. The equipment is arranged so that any one of a team of operators is in a position to record and handle any call. On those calls on which the number of the called subscriber is furnished, the operator will make the initial attempt to complete the connection while the subscriber remains at his telephone. Toll calls handled in this manner receive very fast service, it being possible, in most places, to give service on upwards of 80 per cent. within two minutes from the time the call is received. I think the underlying principles regarding the combined line and recording method and its advantages are best brought out by a brief review of the former toll board operating plan and some of the conditions which led to the development and adoption of the improved method.

In the past, toll board operation has been based on the principle of separating the recording work from the actual handling of the call over the toll lines. In the smaller offices, this has meant very little in the way of specialization in the operating work or in delays in handling the toll service, but in the larger offices the separation has been definite as between the recording and line board work, and in addition it has been considered desirable to handle outward traffic on a point-to-point basis. If the handling of a toll board call is traced under these conditions, we find that the call is given by the subscriber to an operator at the recording board, who records the necessary ticket details and advises the subscriber that he will be called when his connection is ready; the ticket is then sent by mechanical or messenger distribution to the particular positions where traffic to the city called is handled. Calls requiring reference to a directory to obtain the number of the station called are first sent to the directory positions and then to the line board.

This general method of handling traffic has appeared to have several advantages. The separation of the recording and the line board work allowed of some economies in switchboard equipment and facilitated training and supervising problems. The handling of calls on the point-to-point basis kept the toll lines in control of relatively few operators and resulted in some advantages as individual operators became acquainted with the peculiarities involved in handling traffic over particular routes. Another important reason for separating the line work involved in handling the call from the recording was the desirability of providing fast answers to subscribers over the recording trunks, and difficulties have been experienced in the past in meeting this requirement without a separation.

Improvement in Toll Board Operation

This former plan of handling toll board traffic has worked out well and toll board service has steadily improved. Since 1920 the speed of service on calls handled by this plan has improved from an average of 13 minutes to an average of 7 minutes in 1925. It became clear, however, that it would be difficult to make further substantial improvements in the speed of service on the former basis of operation because of the time required to transfer a ticket from the recording board to the line boards and the interval before operators working on a point-to-point basis were available for handling the call. In the continued efforts to improve the service, therefore, the possibilities of combining recording and line board work became more attractive. The introduction of the two-number toll board plan, which has come into quite general use in the larger cities, was a step in this direction, for station to station business and the satisfactory results obtained on this basis seemed to indicate that under present operating conditions it should be possible to handle most toll board business, including person-to-person traffic, by a similar process. Preliminary experiments with combined line and recording operation bore out these indications and the method was introduced in several medium sized toll offices and subjected to careful observation and study. The results have been so satisfactory that the plan has now been recommended to the Associated Companies for general adoption. In connection with this whole activity, I think it only fair to say that the handling of toll board business generally on a combined line and recording basis has been made possible very largely by the marked improvement in operating technique and in supervisory work that has been brought about in the last few years.

Combined line and recording is being rapidly adopted throughout the system. Fifty of the 250 largest cities, together with hundreds of smaller places, are already

operating on the new basis and giving subscribers the benefit of the improved service. By the end of 1926, 150 of these larger cities will be using the new method. In some of the largest cities adoption of combined line and recording will be dependent upon major changes in equipment arrangements and there are still some important questions to be settled regarding the applications of the plan in large metropolitan areas. The early solving of these problems is expected and this will permit the continued extension of the new method until the large bulk of toll board traffic throughout the country is handled on this basis. In this connection it may be well to mention that there is a small amount of long haul and scattered toll business for which combined line and recording does not appear to be the best solution.

Some Service Advantages

In concluding this discussion of the combined line and recording plan, I should like to emphasize again the service advantages. The speed improvement will depend upon the proportion of total business on which the operator can proceed with the call as soon as it is received. Perhaps the most important factor in handling a large part of the traffic on this basis is the furnishing of the number of the called telephone by the calling subscriber. It is clear, therefore, that every effort should be made to educate toll users to furnish the telephone number wherever possible and this should not be difficult since it improves their service so materially.

In places where combined line and recording has already been adopted, the speed of service is usually not over half as long as on the former basis of operation. In some places, with favorable conditions, the results have been even better; in several cities where the average speed of service formerly was 5 or 6 minutes (remarkably good results under the old plan) the speed is now slightly over 2 minutes on the average. These average figures do not quite tell the whole story due to the fact

that the new plan allows of a much higher percentage of calls receiving service in a very short interval. In some cities where numbers are generally furnished, subscribers are now receiving service on 60% of their toll board calls within 2 minutes as compared with 10% formerly. It is this very prompt handling of many calls that appears to have the largest appeal to the toll using public who have been generous with their favorable comments regarding the new service. As might be expected, this reaction is greatest with the fast handling of fairly long haul calls. The possibility of a subscriber removing his receiver, asking for long distance, placing a call for a city 100 or 500 miles away, remaining at his telephone as on a local call and finding himself in communication with the person to whom he wishes to talk, all in a minute or a minute and a half is an attractive one. With the combined line and recording plan this grade of service is being given on a considerable proportion of the calls.

K. W. WATERSON.

Details Multiply

AS we review the amazing progress in the telephone art that half a century has witnessed, our attention not unnaturally finds itself focussed on a few sensationally striking achievements. Clustered about the repeater tube is a galaxy of inventions and scientific developments that have stricken from telephony the fetters of distance, making trans-continental communication by word of mouth an every-day affair. Culminating in the carrier system we find another brilliant group of the products of research which have made it possible for wire circuits to convey, simultaneously and without interference, more messages than ever before. Examples of other towering landmarks along the highway of progress might readily be multiplied many fold, but it is not with this aspect of the great growth of telephony that we are to deal at this time. Instead of contemplating the majestic edifice in its entirety, let us approach it, microscope in hand, bent on examining the minute grains on whose integrity the firmness of the structure depends. The foundation stone, upon which rests the continuity and reliability of Bell System service, is the faithful performance, day after day, of a myriad of tasks by legions of loyal employees.

Making and Splicing Cables

In the cable shops of the Western Electric Company's factory stand rows of gigantic lead presses. These huge machines encase, in metallic sheaths, the underground and aerial cables in which are now to be found nearly ninety per cent. of the forty million miles of wire used in the plant of the Bell System. If the sheaths of all the cables in the Bell System were stripped off, flattened out and joined together to pave a roadway twenty feet wide, there would be enough to stretch from New York to Colorado. A tiny hole in the sheath of one of these

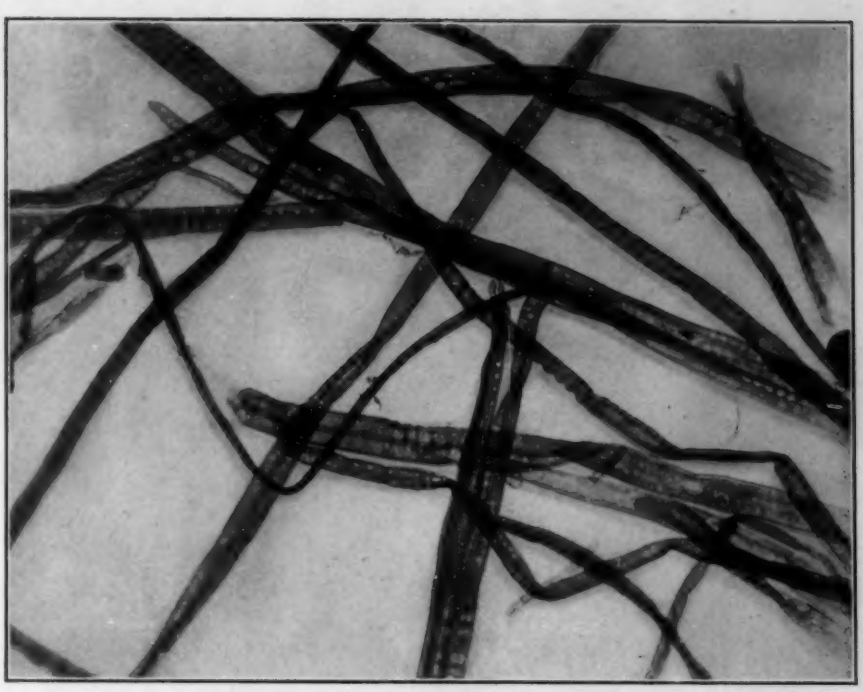

Fig. 1—Properly prepared fibres of suitable length to make satisfactory paper for insulating wires in telephone cables.

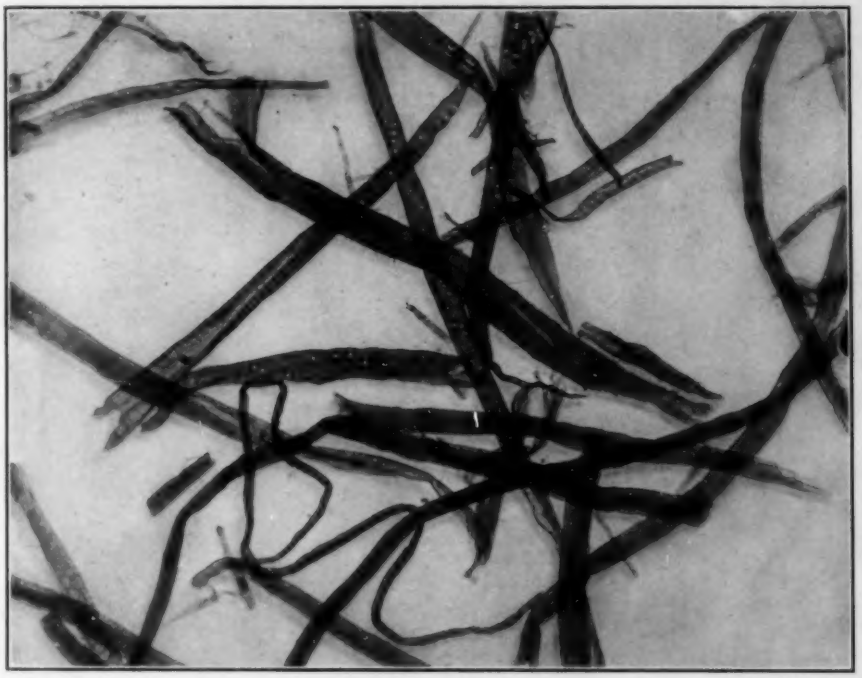

Fig. 2—Improperly prepared fibres which are too short to make satisfactory paper for insulating wires in telephone cables.

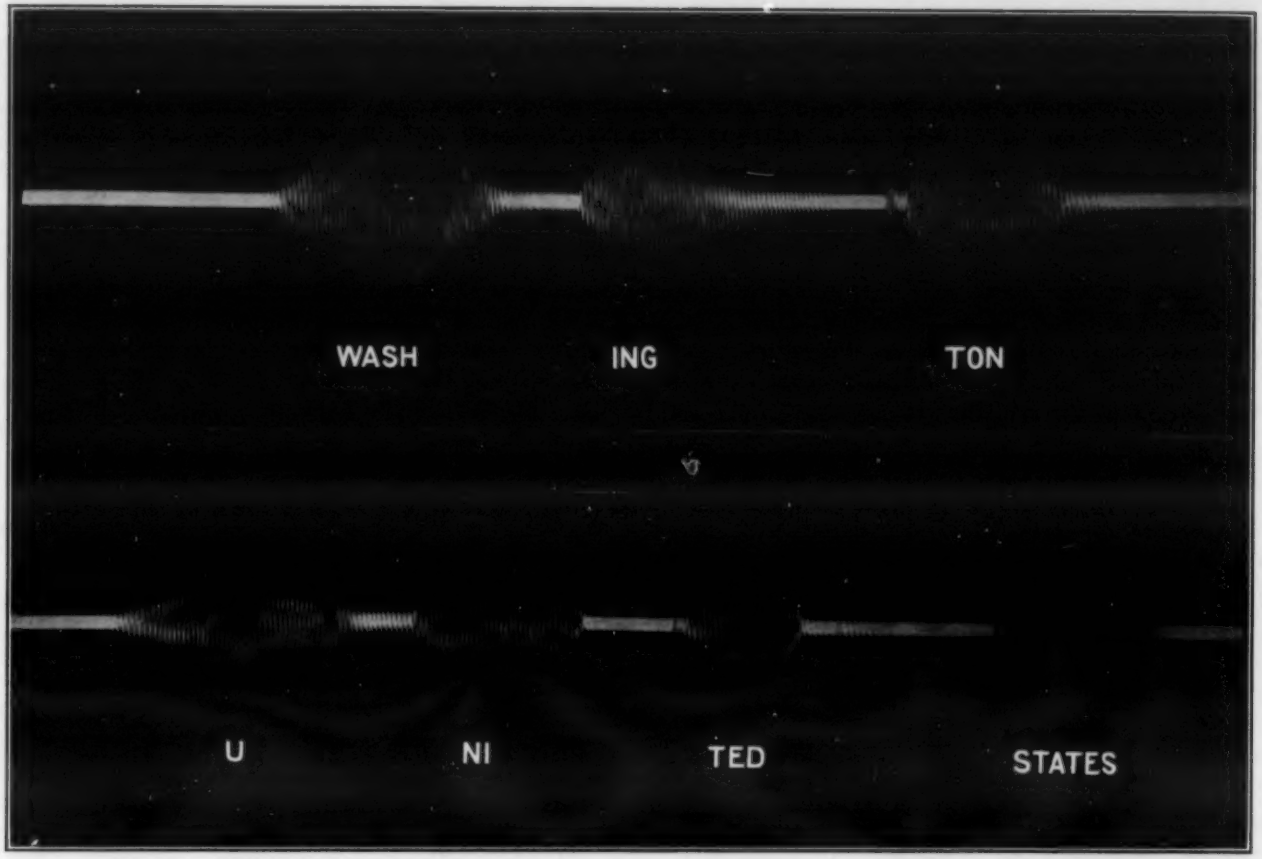

Fig. 3—Oscillograph records showing the fluctuations in the electrical current when the words "Washington" and "United States" are spoken into the telephone transmitter. The speed of the film was about one foot per second.

cables may readily admit enough water to destroy the insulation and render useless the wires within,—sometimes as many as 2,400. There can be no relaxation of vigilance on the part of the experts who control the mixture of the metals of which the sheath is made and the many technicians whose duty it is to guard against the occurrence of pin holes or other defects in the sheaths of these cables as they are being manufactured. The machines do their part wonderfully well, but, as Kipling says, "Things never yet created things." Human supervision and alertness in controlling the manufacturing processes and unremitting watchfulness in inspecting and testing the finished product are essential requirements in turning out cables as nearly perfect as are those needed to give the American public telephone service of the high standard of reliability that it now enjoys.

In the telephone cables, the insulating material wrapped about each wire is dry paper. It is a matter of the utmost importance that the various properties of this paper should be suited to the conditions of its use. It must possess sufficient breaking strength to be successfully applied to the wires, coupled with the ability to withstand twisting and bending. It must suffer no injury when impregnated with the wax used in boiling out moisture from the splices. It must have the desired electrical properties. It must be durable, for, should it contain the seeds of its own decay, the result would be a calamity in the plant. No untried material can be allowed to enter into its composition until the most searching tests have demonstrated the suitability of the new material to meet all of these conditions. The many physical and chemical tests that are made of this cable paper are supplemented by microscopic examination using extremely high magnification. The accompanying illustrations show how cable paper fibres appear when thus magnified. Figure 1 shows fibres of sufficient length to give the desired properties. The fibres shown in Figure 2 are too short to be satisfactory.

But it is not enough that cables shall be practically faultless when they leave the factory. From that time until they take their places in the working plant of the telephone system, through every operation of placing and connecting, constant care must be exercised lest they suffer some concealed injury that, later, will cause them to fail in their duty. Every twenty to forty rods, expert splicers connect together, according to a prearranged plan, the hundreds of tiny wires which are the pathways of speech and hermetically seal the sheath when the splicing job is done. While the splicer is performing his work he must keep the cable dry regardless of whether he may be dry or not. In the recently completed cable, stretching 861 miles from New York to Chicago, no less than 45,000 of these wire joints enter into each circuit used for one conversation. In the cable plant of a large city, the number of joints must be reckoned in millions. When one realizes that a single defective joint may prevent or seriously impair talking over one of these circuits, he is lacking in his appreciation of faithful devotion to the daily task if he fail to admire the zeal of the cable splicer in upholding the traditions of the service.

Switching Apparatus

It is not alone in the cable plant that these high standards of excellence are imperative if disaster to the service is to be avoided. The demands that the normal operation of the system make upon the complicated switching apparatus employed in the telephone central offices for interconnecting the subscribers' lines are truly astonishing. To establish a telephone connection between two subscribers in a manually operated telephone system may require the opening and closing of about one hundred and fifty electric switches, and, in certain automatic systems, nearly two thousand. As a large proportion of these operations is performed by electrically operated relays, it is apparent that these pieces of apparatus must work both quickly and reliably and that

they must maintain a high degree of stability throughout a long period of service. Whether or not a piece of apparatus of this kind will meet the service requirements thus imposed upon it is not left to chance. Before beginning the manufacture, by hundreds of thousands, or even millions, of a new type of apparatus, like these relays, samples are put through extended life tests in the laboratories where they are subjected, in a period of a few weeks or months, to as many operations as they would normally be called upon to perform in many years of actual service. By means of these accelerated tests, any weak points in the design or structure are detected and corrected. Had the value of our modern methods and practices been duly appreciated, I have no doubt that the Deacon, on the completion of his wonderful "one hoss shay" would have set up his first masterpiece on a specially designed testing machine that would have logically put the wheels through a predetermined number of rotations and bumped it about in a manner planned to reproduce the prevailing and expected future conditions of "shay" travel. On the satisfactory completion of his tests, he might have embarked on quantity production of "hundred year shays" with the comfortable assurance that "naow she'll dew!"

Who amongst us knows much about palladium and its use in the telephone plant? Palladium is not a common metal but it is less rare and expensive than platinum. For many years it was thought that platinum was the only metal that would serve for the millions of delicate contacts through which the telephone currents pass in relays, spring-jacks, desk-stands and other essential parts of the telephone system. As the fruit of long, arduous experimentation and research in the laboratories of the Bell System, the amount of platinum used for these electrical contacts was first reduced by improved processes of manufacture, then the less expensive palladium was found to be suitable for many types of contacts and, finally, a still less costly alloy of platinum and

other metals came into wide use as a substitute for platinum in these contacts. A small matter, do you say? In one sense, yes, but the savings from these three steps amount to no less than five millions of dollars in the first cost of apparatus added to the plant of the Bell System in a single year!

In switchboards of the manually operated type, there are used, by the operators in connecting subscribers' lines together, great numbers of flexible cords, each containing three conducting braids of tinsel and furnished at both ends with plugs for insertion in the spring-jacks of the switchboards. Savings aggregating several millions of dollars each year have been realized in the Bell System by increasing the flexibility of these cords and extending their life by numerous improvements, each making its contribution toward increasing their durability.

How many of us know that the cord trailing from our desk stand is carefully waterproofed so that the telephone will not be put out of order should a wet umbrella be rested against the cord, or a window be left open so that the cord becomes rain-soaked? Or that samples from every lot of transmitters that is made are thoroughly tested for weeks to make certain that their efficiency is constantly kept up to the mark?

Not only does the need for infinite care make itself apparent in the design of the multifarious details of the central office switching equipment, but to install these equipments and to connect them up for service demands the most painstaking and thorough standards of workmanship. Vast numbers of soldered connections between wires and apparatus play a leading part in this work. Each and every one of these soldered joints must be a good and true contact, so well made as not to contain the germ of future trouble by working loose. The importance of this will be instantly apparent to every radio amateur who has built his set. The sputtering and frying sounds that a loose connection causes in a radio receiving

set would be just as exasperating and intolerable in a telephone line. A good sized manual switchboard with its frames and appurtenances will contain no fewer than a million of these soldered connections; a typical large machine switching central office will have as many as 2,500,000.

Our Operators

The women of the System, who constitute the loyal operating force, have never failed to attain mastery over the multiplication of details that inevitably have had to be faced in switchboard operating as the business has grown, demanding more and more central offices in the larger cities with the intricate plant that serves to establish connections between them. A large proportion of the fifty million calls a day in the Bell System are handled by this faithful force with errors so few and far between that when a mistake is occasionally made, it attracts our attention by its very rareness. And it must never be forgotten that, in times of danger and disaster, the operator is the nerve-center through which the forces of defense and rebuilding are marshalled.

Only One Best Way to Do the Job

How do these telephone plants that serve the Nation grow? As in a tree, new cells are formed each year, taking their places alongside the older cells, so the telephone plant grows by the building of a stretch of pole line here, the erection of a cable there, the installation of a telephone set in someone's home or office. Even this degree of separation of the elements of the complex structure fails to bring us to the last analysis. In executing each of these varied additions to the plant there are many detailed operations to be performed. Sometimes there are dozens of different ways in which each of these may be carried out. In so simple a procedure as drawing a cable into an underground duct, there are several different ways

of setting up the cable reel, of rodding the duct and removing obstructions from it (if any there be), of attaching the pulling rope to the cable and preventing damage to the cable end, of lubricating the cable, of feeding it into the mouth of the duct, and other details too numerous to mention.

Scarcely may a man lift his hand to perform the smallest act without being confronted by a choice between several methods of performing it. Generally speaking, of all the various ways, only one is the best, the safest and the quickest. If there were no coordinating and standardizing agency to study each of these separate elementary operations, to scrutinize the results obtained and to consider the risk of injury to public, workman and material, in short, to arrange for the best way of performing each act, we should expect to find one group of people doing the job one way and another group, somewhere else, doing the same kind of thing a different way. But it is not so. Each man has his text book of standard methods showing him by pictures and descriptive matter, phrased in simple language, what careful engineering study has demonstrated to be the right way of executing each portion of his daily task. This is the reason why, throughout the Nationwide System, there is found such truly astonishing uniformity of adherence to the best practices.

Frequent, Orderly Testing Anticipates Trouble

A telephone plant, well designed and admirably constructed in every respect, but not kept up to the mark from day to day, would soon fall into a state of general debility inexorably reflected in a lowering of the grade of service. Rot and rust in the out-of-doors plant take their daily toll. Dirt and dust in the central offices would speedily affect the operation of the delicate switching mechanisms were eternal vigilance not exercised. It is only by frequent and orderly testing processes that many troubles can be detected and repairs made before the

trouble becomes so serious as to affect the telephone service from the subscribers' standpoint. Cleverly contrived devices placed in the hands of the maintenance men enable them, by the exercise of expert skill acquired through long experience, to locate hidden defects in cables and wires with a degree of precision that seems marvelous to the uninitiated.

At every point throughout this broad land where limbs of trees overhang or project near telephone wires on poles, there will be found, not far away, a maintenance man, whose job it is to make sure that these limbs are kept properly trimmed so that, when it becomes a vital matter hurriedly to summon the doctor or the police or fire department, it shall not be found that the telephone service is interrupted. And in this man's pocket will be found a booklet, carefully prepared under the guidance of forestry experts, showing him, in every essential detail, how to trim trees, so that his work will be a benefit, rather than an injury, to them.

Our Linemen

Time was when transposition systems and circuit arrangements on poles were less complicated than they are today and the pioneering nature of the lineman's job was one of its more outstanding characteristics. Although complexities have increased, vastly improved transportation facilities and tools have been placed at his command, enabling him better and more effectively to cope with the situations that confront him. Throughout all these changes his spirit of service has remained unimpaired, spurring him on to spare no effort in restoring the threads of speech in the face of hardships after sleet storms or flood.

Maintaining Transmission Standards

In order that John Doe and Richard Roe may hold a satisfactory conversation by means of the telephone, it is

not enough merely to connect their transmitting and receiving instruments together by wires. If each heard the other's voice, but only in a blurred and distorted fashion, he would not be well served.

Unlike the transmission of electricity for power and lighting purposes, which employs a current alternating a particular and fixed number of times a second, telephony demands the transmission of alternating currents ranging from about two hundred to as many as three thousand alternations a second. A picture of one of these complex telephone currents is shown on a preceding page.

Distortion of the shape of the tiny fluctuations of this wave, as the current passes over the line, makes the voice less and less recognizable.

The minuteness of the telephone current is difficult to comprehend. Electric power is ordinarily generated and transmitted in millions of watts. On the other hand, the telephone transmitter delivers to the line only a few thousandths of a single watt, and, frequently, more than 99% of this power is necessarily dissipated along the line. Every piece of apparatus, coil, relay or what-not, that is connected into the telephone circuit, must be skillfully designed so as to interfere to the least extent with the transmission of these delicate and diminutive currents. But this care in design is not enough. Of the many little happenings, such as the shifting of connections, that so frequently take place as the plant lives and grows, not one ever improves the transmission of the voice, but any one, if improperly executed, will tend more or less to impair the loudness or distinguishability of speech. To prevent gradual debasement below suitable standards of transmission, many pieces of cleverly contrived testing apparatus employing minute currents that cover the range of the human voice, have been devised and are in regular use for the purpose of detecting and locating such unwelcome conditions in the telephone circuits and thus enabling the maintenance forces to correct them.

Telephone Directories

For telephone directories, the Bell System uses about 30,000 tons of paper a year. When one pictures, in his mind's eye, the vast number of pages, closely filled with names and numbers, contained in these directories for more than eleven million subscribers, the task of keeping them free from errors looms large. Expert attention has been directed to developing a style of type, for telephone directories, that provides the highest degree of legibility for a given size, and advantage is taken of every opportunity to avoid waste of material in trimming and from undue margins.

The Motor Fleet

The words "Telephone Service" bring to mind a huge aggregation of people and parts cooperating to a common end, namely, furnishing to the people of the Nation an essential means of communication, but, in the picture which they conjure up to most of us, the motor vehicle does not appear. Yet it performs yeoman service in promptly and safely transporting the quantities of bulky and heavy materials used in constructing and maintaining the telephone plant and the gangs of men who put these materials into place during emergencies as well as in the normal operation of the business.

We are living in a mechanical age and the eleven thousand motor vehicles of the Bell System play an important part in speedily transporting no less than 25,000 men, with their tools and supplies, from their bases of operation to wherever their day's work is to be found. Not only this, but the truck engines are employed to operate derricks for handling poles and other heavy parts, and winches for pulling in cables and for many other purposes, thus permitting important reductions to be made in the sizes of working gangs.

Loyal Workers Maintain Bell System Ideals

In this brief description of a few of the instances of the multiplication of details and the painstaking, never ending care which they require, in order that high standards of service may be met and maintained, it has been impossible to mention directly more than a few classes of Bell System workers to whom tribute is due.

If they could pass before us, in brisk review, like an army, we should see many divisions, at the head of each the generals with their staffs, who plan the far-reaching operations, followed by the serried ranks of those who carry out the maneuvers. Their banners are, first, the flag of our Nation, and then the emblem of the Bell System. On the breasts of many are insignia standing for honorable service in the World War, where thousands of them devoted their special qualifications to the service of their country in the Signal Corps of the A. E. F. and elsewhere. A host of others wear the symbols of many years of faithful service in the ranks of their various companies and some the meed of outstanding deeds of heroism in the face of fire or flood. Here comes a regiment of researchers in the realms of science, qualified by years of training to question nature and interpret her language in revealing the fundamental scientific knowledge upon which rests the work of another regiment of inventors, engineers, and designers who mould these principles into tangible improvements in thousands of things.

And what is this great division of 40,000 men and women? They come from the manufactories which turn out each year $175,000,000 worth of apparatus, cables, and in fact, 110,000 different kinds of parts that go into the telephone plant. With them are their leaders who direct the operations and invent and design the highly specialized tools and processes used in making many of these parts, and here is a corps whose duty it is to schedule the production and distribute and warehouse the products.

More engineers! This time those who pry and peer

into the future, seeking to see the plant as it should be planned to meet in the best way the conditions and requirements fifteen or twenty years from the present, and those who laboriously figure out where and when each and every addition to the plant shall be placed.

Approaching in the distance are the three great divisions of those who construct the plant, operate it and maintain it. In the operating division are the 150,000 women whose deft fingers daily weave the warp and woof of conversation at the switchboard looms. Presently will come those who handle the accounting and billing, at their head the planners who think out the best methods for them to use and who delve into all sorts of office appliances in order that machines may, as far as possible, relieve human effort. From dawn to dusk this telephone army marches in review, not for a single day, but for three days before we have seen them all pass.

It is their conscientious devotion to their daily tasks that has made the ideals of the Bell System what they are today.

F. L. RHODES.

Maintaining the Talking Efficiency of Telephone Circuits

THE plant used for supplying telephone service involves important and difficult problems not only in its design and construction but also in its maintenance. When with great care the additions to the telephone plant have been designed properly and constructed in such a way as to care adequately for the needs of the subscribers, the problems of the telephone company are not ended, they are simply begun. Telephone circuits are necessarily complicated both from the mechanical and the electrical standpoints. The telephone lines running in cables under our city streets, on poles and stretching out along the country side are, of course, also subject to the elements and many other things beyond our control. Like any other comprehensive mechanical or electrical systems telephone circuits will not, of course, continue to operate reliably and at high efficiency without continued watchfulness to keep them in a state of freedom from impairment; hence, the great importance, in maintaining a high quality of service to the subscriber from all standpoints, of the various phases of preventive maintenance.

The Need for Inspection

From the fact that poles, for example, gradually decay at or just below the ground level, it is clear that if left without attention they would ultimately become too weak to carry the loads applied to them and fall down, thus interrupting service, and this might often take place without any previous indication to the casual observer that the pole had been greatly weakened. Therefore, we make careful periodic inspections of the poles, clearing away the earth from them at the ground line and testing the wood for soundness so that before a pole becomes sufficiently weak to form a menace to the stability of the line, it may be strengthened or replaced.

Similarly, a great many things are continually taking place which tend to reduce the efficiency of the circuits for the transmission of speech. Many of these things can be found by a careful inspection as they result from wear, tear and breakage in the use of apparatus or from the tarnishing of metal, etc. These types of impairment, as a rule, can be taken care of by the faithful carrying out of adequate inspection routines and without any special electrical tests.

Many Electrical Impairments Are Hidden

On the other hand, many very important ways in which the telephone circuits may become impaired cannot be detected through physical examination even by an expert. Electrical defects develop which are hidden in the inner recesses of apparatus. Changes occur in the characteristics of the materials of which the circuit is made, corrosion of joints in wires, deterioration in the properties of insulating materials, reduction in the strength of batteries; these, and many other things, are the types of things constantly tending to reduce the transmission efficiency of telephone circuits which can be detected only by suitable electrical measurements.

Some of these impairments are, individually, extremely serious and, if not detected, would result directly in a very poor quality of service. Many of them may, of themselves, be relatively slight but the cumulative effect of a number of these throughout the circuit may produce very serious effects.

An illustration of some of the types of troubles not due to ordinary wear and tear is given in Figure 1 together with an indication of their effect on telephone transmission. This diagram indicates a call from a local battery station over a direct toll circuit to a common battery station in a multi-office plant, the subscribers' stations and the various offices through which the circuit passes being indicated merely by blocks in the diagram. The

line marked "A" represents the relative transmission level at various points in the circuit if there are no maintenance difficulties. The overall transmission under these conditions is 25 units which represents a very satisfactory talk. The line marked "B" shows the relative transmission over the same circuit with a number of transmission troubles some of which could not be detected and none of which could readily be detected by the inspection routines. The combined effect of the six troubles indicated in this case is to give an overall equivalent of the circuits of 49 units representing a condition in which it would be impossible to carry on a satisfactory conversation. This is an extreme example and is given simply by way of illustrating the importance of any one of the types of troubles referred to and to show the serious cumulative effect of troubles were they not avoided through preventive maintenance.

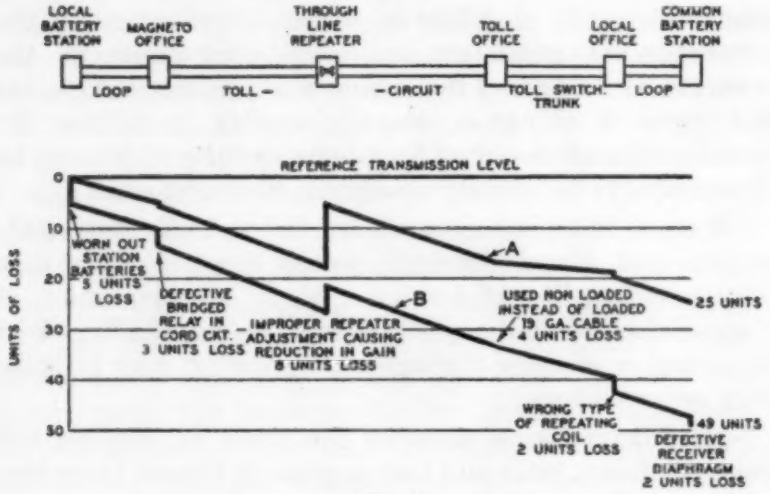

Fig 1

Early Tests for Electrical Troubles

How shall the presence of these defects be detected and when detected, how shall they be located? Since the beginnings of telephony there have been available certain

simple tests for checking some of the electrical characteristics of the circuits. These tests include principally tests with a battery and voltmeter for insulation resistance and tests with a Wheatstone bridge for conductor resistance and also similar tests for the location of insulation faults. These tests have been of inestimable benefit in maintaining the telephone plant. However, there are a great many types of troubles which they cannot detect. For example, of all of the faults shown in Figure 1, probably only one could be detected by these means.

The criterion of the transmission efficiency of a telephone circuit is in the clearness with which it transmits speech. Obviously, a rough check of the transmission efficiency of a circuit can be made by talking over this circuit and this test can be developed into a quantitative test by comparing the talking qualities of two circuits, one of which is an adjustable standard circuit whose efficiency can be expressed in standard units. Before the last ten years, tests of transmission efficiency were carried out in this way, and many of us may recall hearing the tedious counting, "1, 2, 3, 4, 5, on one; 1, 2, 3, 4, 5, on two" which characterized these tests.

Such a method has, however, extremely severe limitations. Of course, it could be used only to test loop circuits because of the fact that the transmitting and receiving ends of the circuit must be at the same point. It was limited in precision by the precision of the ear in detecting variations in loudness in speech. Most important of all, it has the difficulty of requiring experienced and trained men and of being lengthy so that this type of test was too slow and expensive for general use in plant maintenance routines.

Conditions of the Problem

In view of these difficulties it was obviously desirable to develop more satisfactory means for testing the efficiency of telephone circuits. For all electrical parts of the

circuit, one way of making such tests would be the measurement of the amount of current received when a given current is transmitted into one end of the circuit. In order to indicate the efficiency of the circuit for transmitting the voice, however, it is obvious that the currents used in such a test must be somewhat similar to the currents generated by the voice in speaking over the circuit.

The voice currents are derived from the action on the transmitter of the sound waves caused by the speaker's voice. These sound waves represent an extremely small amount of energy so that if transformed by the transmitter at 100 per cent. efficiency into electrical energy it would be less than one millionth of the electrical power necessary to light an incandescent lamp. Fortunately, present types of transmitter produce a large amount of amplification in this energy and deliver to the telephone line voice currents representing several hundred times as much energy as is produced by the speaker's voice. They are, however, still extremely minute and, furthermore, at the receiving end of a telephone line the electric power of the voice currents is often only a fraction of a per cent. of that at the transmitting end.

In addition to being extremely small, the electrical characteristics of the telephone currents are extremely complex. The accurate reproduction of a telephone current would involve the combination of a very large number of alternating currents having frequencies from 200 cycles up to 2,000 or 3,000 cycles or more and changing very rapidly in relative magnitude. The complication of these currents is illustrated in Figure 2 which gives two pictures of telephone currents. The upper part of the picture shows the currents corresponding to the words "Bell telephone." In order to get the entire phrase on a film, however, it was necessary to very greatly compress and condense the curves so that only the general outline can be seen. This is illustrated by the lower part of the figure which shows the appearance of the vowel "E" alone when the film is running ten times as fast as the film in

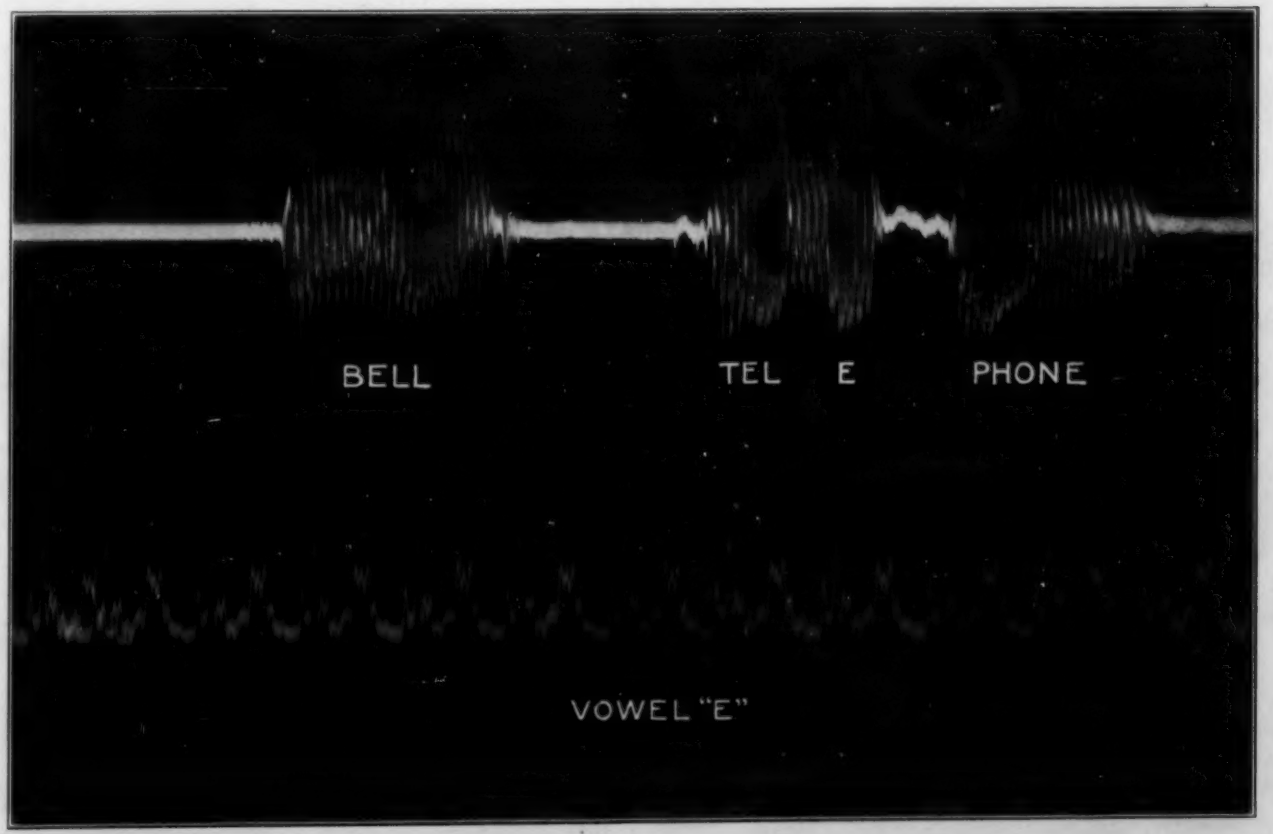

Fig. 2

the upper part of the picture. The figure shows the current corresponding to the vowel "E" for about one-tenth of a second. Some other parts of the telephone currents, particularly those representing consonants, are even more complicated in shape.

For most routine testing work it is not necessary to accurately measure the characteristics of the circuit for all components of the voice currents but the measurement may be confined directly to determining whether or not the circuit has changed in characteristics. For this work it has been found that a sufficient indication can generally be obtained by using for the measurements, in place of the very complicated voice currents, a very small alternating current having a frequency of 1,000 cycles per second, that is, reversing in its direction of flow 2,000 times per second. These currents can be read by a meter, greatly simplifying the work.

Improved Testing Methods Developed

When the active development of improved transmission measuring apparatus was undertaken some thirteen years ago, quantitative measurements with currents of this type constituted a high grade laboratory investigation which could be made by the scientist or research engineer with delicate apparatus but which were not suitable for everyday use by the field maintenance forces. Through a very interesting series of developments several of which take advantage of the extraordinarily useful properties of the vacuum tube, many pieces of apparatus have been made by which tests of this character are carried out successfully as a part of the everyday routine. Although making sensitive and complicated measurements, this apparatus has been made sufficiently rugged and simple in operation so that it is placed in the hands of the men directly responsible for maintaining the telephone plant and very satisfactory results are obtained in their use of it.

A good many of the tests, particularly the tests of toll circuits, are made at night when the circuits are relatively free from traffic. Every night in all of the largest toll offices of the country, experts are busily engaged at testing desks ordering up circuits, adjusting apparatus, and making and recording the measurements which show the electrical efficiency of the circuits and when these are found to have suffered impairment, directing the search for the cause of impairment. By this means the impairments which are found can be eliminated so that satisfactory service may be insured before the rush of business on the following day.

Routine Check of Transmission Efficiency

A summary of the routine transmission measurements gives a very good indication of the maintenance condition of the plant as regards all conditions which effect transmission efficiency. The results are summarized so as to distinguish between the impairments which could not be detected except by the electrical tests and the impairments depending upon wear and tear, etc., which could be taken care of in the daily inspection routines and in this way a check is obtained not only of the transmission condition of the plant but also of the effectiveness with which the everyday routines are being carried out. To a very large extent these tests permit the clearing up of troubles while they are still in the incipient stage and prevent the development of impairments which would seriously react upon the telephone service.

As a part of the routine the results of these measurements are analyzed from the standpoint of type of trouble and this analysis gives many indications of value as regards the technique and as regards the administration of the general maintenance work. When trouble is indicated by these measurements the next job is to locate it. If it is in the apparatus at one end of the circuit, it can readily be located by a process of segregation. When, however, the trouble is out on the line, the problem is quite different

and here again the development of suitable methods of test has given an added assistance to the maintenance man. Several tests of this nature have been developed and the use of one is illustrated by Figure 3. This figure represents one of the electrical characteristics of a circuit which can be determined by suitable measurements from the end of the circuit and shows the variation of this characteristic when measured with currents having frequencies from 200 to 2,000 cycles. If the line were free

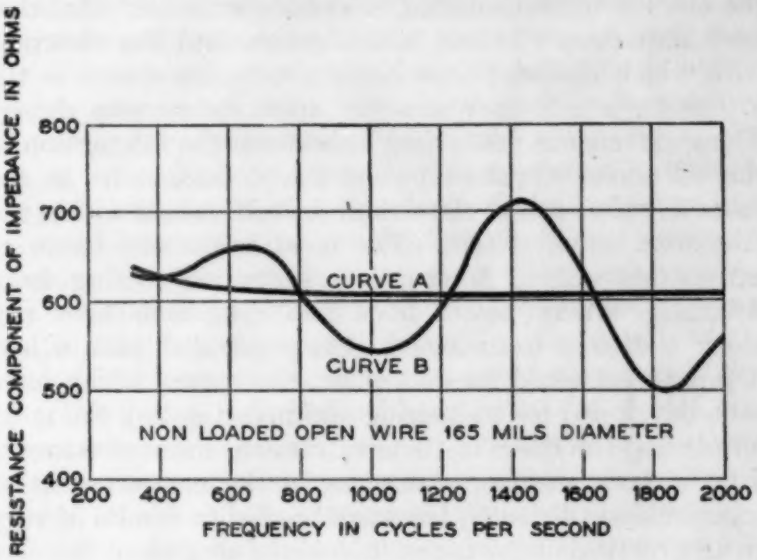

Fig. 3

from defects, the plot of this characteristic against frequency would give Curve A of the figure showing a slight and gradual change over the frequency range. In the particular case illustrated, however, the results obtained were those shown by Curve B, which gives a humpy curve which oscillates around Curve A. By an ingenious application of electrical theory the relation has been determined between the shape of Curve B and the location of the defect so that in this case, for example, it was possible to compute from the curve that there was a defect in the

line 105 miles from the point at which the test was made. Tests of this sort have the advantage that they indicate anything which will affect the transmission characteristics of the circuit whereas the simpler type of trouble location test heretofore available would not give any indication of many of these defects.

Extraneous Induced Currents

The discussion given above refers to the efficiency of the circuits in transmitting telephone currents. Another very important element which enters into the clearness with which the telephone circuits transmit speech is the extent to which they are free from extraneous noises. These extraneous noises may arise from the interaction of the telephone circuits on each other, from noise in the room at either end of the circuit or from causes within the telephone circuit itself. The most important cause of extraneous noises, however, is induction arising from situations where power lines and telephone lines run along the same routes and closely parallel each other. A great deal could be said about the means which have been developed for measuring and investigating the magnitude and the effect of these extraneous induced currents from various sources. Here, as in the measurement of transmission efficiency, the work has led to results of very great practical importance in maintaining the efficiency of circuits.

With reference to extraneous currents produced by parallels with power circuits, an important phase of preventive maintenance is the cultivation of a close mutual understanding between the power company and the telephone company officials and employees so that each will appreciate the problems of the other and so that the companies will cooperate cordially in taking proper steps to prevent the establishment of conditions which would result in inductive disturbances. In order that this may be carried out fully, it is, of course, important to plan ahead, so far as possible, with the power companies so

that the plans for future development of each system will be made with due regard to the other system. A cordial cooperation of this sort if carried out is a primary factor in obtaining the best engineering solution for this important problem.

Investigation of Cases of Trouble

Whereas preventive maintenance of the types which we have been discussing is essential, it is also very important that provision be made for the adequate investigation of cases of trouble as they arise. A very considerable advance in the methods of finding troubles which develop in toll service has been made in recent years by the general adoption of improved routines for following up promptly and effectively transmission troubles which are brought to the attention of the operators by subscribers or which come to the attention of operators and service observers in other ways. For each such trouble the operator or observer is instructed to make out a ticket similar to a message ticket giving the details of the call and the operator's judgment as to the type of trouble. This ticket is forwarded at once to the Wire Chief who immediately orders up for test the facilities involved. By this means work is greatly expedited in the clearing of troubles. An important feature of this routine as regards cases in which the subscriber has reported difficulty is the provision that the Wire Chief shall immediately follow up the matter with the subscriber thus showing him that it is receiving prompt attention; furthermore, very often the description which the subscriber can give of his difficulty is of valuable assistance to the Wire Chief in locating the cause of the trouble.

No attempt has been made in this brief article to do more than illustrate by a few typical examples the sort of work which is being done to maintain the talking efficiency of the telephone circuits. The aim is, by covering all parts of the telephone plant with suitable testing methods and adequate testing and inspection routines not only to

promptly clear up any unsatisfactory condition which may have developed but primarily to anticipate as far as possible the development of trouble and catch impairments in their incipient stage. These activities are all directed to the end that the service rendered our customers may be reliable and satisfactory.

H. S. OSBORNE.

EDITOR'S NOTE: Mr. Osborne is Transmission Engineer of the American Telephone and Telegraph Company.

The Aurora Borealis

ON the morning of January 26th of this year (beginning between ten and eleven o'clock eastern standard time) difficulty was experienced in operating the grounded telegraph circuits over a part of the United States and Canada. This was true of the circuits of the telegraph companies and railroads as well as to those of the Bell System. At once the report went out that an aurora borealis was in progress. It was broad daylight so, of course, no aurora was seen but the erratic behavior of the circuits was easily identified with that which years of observation have shown to be usually associated with auroral displays. Whether there actually was an aurora on the day in question will probably never be known because the earth currents which are the direct cause of the erratic behavior of the telegraph lines sometimes appear without the accompaniment of any luminous display in the northern sky such as the term aurora calls to mind.

It is not frequent, to have a display of this sort so extensive as to be severely felt in both Europe and North America. However, one of the most extensive as well as powerful auroras occurred within the memory of all of us,—May 14–15, 1921. This display was brilliant both in Europe and America and the accompanying earth currents were sufficiently severe, not only to cripple telegraph service for the time being but to burn out heat coils and char the paper insulation of cables where these contained grounded circuits. The foreign potentials observed on telegraph circuits in some cases attained momentary values as great as 500 volts.

The Cause of the Aurora

Whence comes the aurora is a question toward the solution of which rapid strides are apparently being made at the present time. We may still be a long way

from the final answer but during the past few years many observations of a significant and fundamental character have been made.

One of the striking characteristics of the aurora is its evanescence. We recall the words of the poet:

> "Or like the Borealis race
> That flit ere you can point their place."

In spite of its ever-changing pattern, a group of Norwegian scientists, favorably located because the aurora is of frequent occurrence with them, have succeeded in taking photographs of hundreds of displays from two different stations and against a background of stars so that from pairs of simultaneous photographs, the position of the aurora in the upper atmosphere was accurately computed. These Norwegian investigators have in this way brought to light some very interesting facts regarding the height of the aurora above the earth and the latitude of its most frequent occurrence. One of the conspicuous characteristics of most auroral displays is a rather well-defined, even sharp, lower boundary. It has been found that for the great majority of auroras, the height of this lower boundary lies between 60 and 65 miles. These same photographs also tell something about the height of the top of the aurora. In six cases, they found the luminosity extending to upwards of more than 300 miles and in one case it reached the height of 375 miles. One conclusion to be drawn from these observations is that the earth's atmosphere is sensible even at these great heights. It was also shown that in the northern hemisphere, the preponderance of auroras occur between latitudes 69° and 72° and that the general direction of the arc or curtain is on the average about perpendicular to the magnetic meridian.

Allied Phenomena of Cosmical Physics

The aurora and the so-called earth currents are but two of the many phenomena of cosmical physics which

are apparently related to one another, but the extent and nature of the relationships is still far from being unravelled. Sun spots, the solar corona, magnetic storms and unusual electrical conditions in the earth's atmosphere are all undoubtedly connected in one way or another with the phenomena of auroras and earth currents. For instance, an unusually large sun spot or group of spots may be the signal for a disturbance of the earth's magnetic condition or an aurora with attendant earth currents or both. On the other hand, the eleven year cycle in sun spot maxima and minima does not seem to be paralleled by an equal periodicity in auroral appearances. One of the world's leading authorities on cosmical physics, after pointing out that the great volume of data at hand does not as yet permit the drawing of any very definite conclusions, says, "One cannot adequately realize the problem they present without a greater familiarity with their nature than has, I suspect, been possessed by some of those who have theorized on the subject." The present writer will refrain from all theorizing, simply stating in brief compass what seems to be the best present-day opinion as to the cause of auroras and earth currents.

The obvious, although perhaps superficial similarities between the luminous discharge of electricity in a vacuum or Geissler tube and the luminosity of the aurora in the upper and therefore attenuated region of the earth's atmosphere brought forth many years ago the suggestion that the aurora might be in the nature of an electrical discharge. This theory is still the dominant one and although many able investigators have attempted to answer the question, whence comes the electric current which discharges itself to produce the aurora and what is the nature of this current,—that is of what type of corpuscles does it consist—the problem is still not definitely solved. Probably the most plausible source of this current is the sun, and in view of our modern knowledge of electrons and protons (the negative and positive

carriers of electricity) it is most reasonable to think of this current as consisting of either a stream of electrons or protons, or perhaps a mixed stream of the two. It is a fact readily demonstrated in the laboratory that a stream of electrons or protons when passing through a rarified gas will, under the proper conditions, throw the gas in their path into a luminous condition. Therefore, if the sun did shoot out streams of either or both of these electrical carriers, these streams impinging upon the upper layers of the earth's atmosphere, a luminous display could reasonably be expected. Why the sun should originate such streams of charged particles is, of course, a matter of conjecture. If it does originate them, there are certain reasons for expecting them to be associated in some way with sun spots.

If the aurora is the result of an interplanetary rain of charged particles driving through the earth's atmosphere, whether these particles originate at the sun or elsewhere, it naturally follows that a corresponding movement of electrical charges would be induced on the surface of the earth, which would be quite adequate to account for the stray currents picked up by grounded telegraph lines. If at any time, earth currents are found unaccompanied by an aurora, it may mean that the charged particles streaming into the earth's atmosphere are too attenuated or perhaps too slow-moving to excite luminosity, or it may be, of course, that this is not the only cause of earth currents.

In order to constitute a successful explanation, the hypothetical stream of charged corpuscles coming from the sun and striking the earth's atmosphere must, of course, account of the curtainlike appearance of the aurora, for the fact that it predominates in far northern and southern altitudes and for the fact that the lower edge of the aurora is sharply defined and found on an average to lie at an altitude of about 60 miles. While it cannot be stated that the theory is entirely satisfactory on all of these points, it is proving very successful as a

working hypothesis and apparently has more evidence in its favor than against it.

The mathematical calculation of the path which a stream of electrons and protons would steer as they move through the earth's atmosphere under the influence of its magnetic field was first undertaken by the Norwegian physicist Birkeland. In order to give his work additional confirmation, Birkeland constructed a large vacuum tube or box, the sides of which consisted of plate glass and within which he arranged a magnetized iron sphere to represent the earth. At this he shot streams of cathode rays and was able to show that under proper conditions, the luminous trail formed upon the surface of the sphere by the impinging rays was quite similar to the usual shape and position of an auroral curtain.

The mathematical work of Birkeland was later reviewed by other Norwegian physicists and with the introduction of certain refinements, the agreement still appears to be satisfactory.

The Auroral Spectrum

One of the most interesting avenues by which the aurora has been studied in recent years, is that supplied by its spectrum. The analysis of its spectrum early brought into prominence the existence of a particular green line which had never been found in any spectra produced in the laboratory. It had a position very near certain green lines in the spectrum of nitrogen, but it steadfastly balked all attempts to establish it as a part of the nitrogen spectrum. The gases which we should most naturally expect to find in the upper regions of the atmosphere are, of course, the lighter gases and particularly hydrogen and helium. The green line of the aurora seemed to be entirely unrelated to the spectrum of either of these gases. One of the interesting discussions of present day physics has centered in the origin of this green line. Vegard, who was associated with Birkeland in the investigation of the aurora, put forth the hy-

pothesis that the green line came from nitrogen at a very low temperature. In the laboratory he succeeded in bombarding nitrogen, which had been frozen by liquid hydrogen and obtained in his spectroscope a very brilliant green line which seemed to correspond in position with the auroral line.

The Canadian physicist McClennan, in repeating Vegard's experiment, thought he found a slight discrepancy. The green line obtained by bombarding solid nitrogen proved not to be a single line but three lines very close together. The auroral line, on the other hand, could not be thus separated. McClennan, therefore, disputed Vegard's hypothesis and by further experimentation strengthened his position by discovering that a vacuum tube containing a mixture of oxygen and helium or oxygen and neon would produce a line apparently identical with that found in the aurora. If McClennan's result is verified it will be the first time that the mysterious line of the aurora has been reproduced in the laboratory. According to McClennan, nitrogen, when mixed with helium or neon, does not yield the auroral line at all. Neither is low temperature necessary for the production of the green line in oxygen and helium. Since both helium and neon are chemically inert gases, the presumption is that by virtue of their presence in the discharged tube the oxygen is thrown into an abnormal condition radiating a green line which is not a part of the normal oxygen spectrum.

Experience of the Bell System

Engineers of the Bell System have been collecting data for some time on effects produced by meteorological disturbances, particularly in connection with earth potential differences and radio transmission.

In the study of earth potential differences, the direct current telegraph circuits of the Bell System which connect widely separated points afford a means for obtaining data. Many practical difficulties arise, how-

ever, such as ground potential disturbances caused by the operation of trolley lines, leakage from conductors to ground which vitiate the accuracy of measurements. Furthermore, when the aurora disturbances are most severe, the first duty of the test board forces is to restore the service on any lines which are affected by it. Many observations have been made, however, in accordance with a prearranged schedule. The results obtained have yielded considerable information as to the characteristics of earth potential differences during such periods of disturbance.

In long distance radio transmission, the observations which have been made by Bell System engineers indicate that meteorological disturbances sometimes have an important effect. Data have been obtained indicating that certain relationships exist between effects produced by magnetic storms and radio reception.

What more significant data may become available in the future it is not possible to predict. Nevertheless, through continuing measurements of earth potentials and radio-transmission phenomena, the Bell System engineers have an opportunity to supply valuable data and give material assistance in the study of those factors being investigated by the cosmical physicist.

R. W. KING.

Economic Notes, First Quarter, 1926

THE American Bureau of Metal Statistics has made and issued a compilation, subject to revision, of the copper consumption of the world in 1925. The Bureau puts the figure at 3⅓ billion pounds, which is in excess not only of the production for last year, which was about 3⅙ billion pounds, but of production in the previous high-record years of 1917 and 1918. The war demands of those years naturally caused abnormally large copper production; the 1918 output, as given by the U. S. Geological Survey, having been exceeded by only a few thousand tons in 1925. The United States accounted for 53% of the copper production of the world in 1925, but for only 49% of the consumption. The American Bureau of Metal Statistics put German consumption in 1925 at more than 510 million pounds, as against only 290 million pounds in 1924.

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PRELIMINARY compilations indicate that Class I railways of the United States during 1925 earned a net railway operating income of nearly $1,137,000,000. This represented a return of 5.63% on the tentative valuation figures of the Interstate Commerce Commission (including additions since the original figure was published), and fell short by less than $24,000,000 of the so-called "fair return" rate of 5.75%. This shortage compares with one of $492,000,000 in the year 1921, when only 3⅓% was earned on the tentative valuation as of that year.

* * *

THE latest available revised estimates of the U. S. Treasury Department indicate that for the fiscal year 1927 the income tax from corporations at the new rate of 13½% will yield $1,150,000,000, while the income tax on individuals under the recently reduced rates of the Revenue Act of 1926 will yield only $456,000,000. If

these estimates prove correct, the corporate income tax will yield just over 2½ times as much as the individual income tax. There have been some interesting shifts in the relative proportions of income tax paid to the Federal Government by corporations and by individuals since 1918. Fiscal year divisions of income tax receipts between the two types are not available. Calendar year figures of taxes payable, as shown by the annual pamphlets, "Statistics of Income," issued by the Treasury Department, give, however, indication of the proportions. In 1918, the ratio of corporate tax payments (including income, war and excess profits taxes, and capital stock tax) to personal income tax payments, as thus shown, was 2.8: 1. In the next four years this ratio—thanks principally to the elimination of the war and excess profits taxes on corporations and to declining margins of profits by corporations—declined to 1: 1. Since 1922, chiefly as a result of the reduction in individual income tax rates, this ratio has risen and, as has been said, the Treasury Department expects it to be as high as 2.5: 1 in the next fiscal year.

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FIGURES published in January and February in the London *Economist* indicate that the world's gold production in 1925 increased over that in 1924. It is now back to a point exactly half way between the high record production for all time in 1915 and the low point for the subsequent period, reached in 1922, the year of the strike in the Transvaal region. Furthermore, the Transvaal in 1925, in registering an output of almost exactly 9,600,000 ounces, made for itself a new high record for all time. This latter development is particularly interesting in view of the fact that the pound sterling practically returned to par during 1925, which meant that last year was the first year since 1915 that the gold-mine owners of the Transvaal had not received a substantial premium (in terms of currency) for their

product. During each of the last three years the Transvaal has produced more than half of the world's gold output. The value of the Transvaal's output last year was more than $198,000,000 out of a total of more than $394,000,000, the value of the output for the whole world. It is clear that we have not yet entered on that period of falling gold production to which some proponents of the theory of a declining price level look forward.

* * *

THE Federal Reserve Board has begun publishing weekly figures of the volume of loans to security brokers and dealers by 61 reporting member banks in New York City. The banks report the loans which they make for their own account, for the account of out-of-town bank correspondents, and for others. The data, which relate to the close of business on Wednesday of each week, go back to January 6th, the first Wednesday of this year. On that date, total loans amounted to $3,141,000,000, of which $1,338,000,000, or three-sevenths, represented loans for the New York banks' own account and the rest for the account of out-of-town banks and others. By March 17th, following and in large part consequent upon drastic declines in prices on the New York Stock Exchange, the volume of loans had been reduced to $2,804,000,000, of which the New York banks were lending on their own account only $1,033,000,000, or three-eighths of the total. Figures published by the New York Stock Exchange of members' net *borrowings*, as of the end of January and February, showed volumes for each date somewhat in excess of 3½ billions, of which about 2½ billions were on demand and a billion on time.

* * *

THE long-awaited report of the Royal Coal Commission of England has been published. The report includes a broad survey of the coal industry and makes numerous recommendations for improving the present

unsatisfactory condition of the industry. Among these, the principal is that the Government should acquire the mineral deposits at a probable cost which the Commission puts at nearly £100,000,000. Operation of the mines, however, would remain in private hands, with the grouping of the mines into more economic units encouraged, though not ordinarily or immediately compelled. The Commission makes various suggestions for lowering costs by eliminating waste in production and in distribution, by certain wage reductions, and through lower transportation rates. The Commission considers indefensible any extension of the present subsidy to the industry, which during the present fiscal year is costing the British Government nearly £20,000,000: "The subsidy should stop at the end of its authorized term, and should never be repeated."

Abstracts of Recent Technical Papers from Bell System Sources

Cipher Printing Telegraph Systems for Secret Wire and Radio Telegraphic Communications, by G. S. Vernam.[1] This paper describes a printing telegraph cipher system developed during the World War for the use of the Signal Corps, U. S. Army. This system is so designed that the messages are in secret form from the time they leave the sender until they are deciphered automatically at the office of the addressee. If copied while en route, the messages cannot be deciphered by an enemy, even though he has full knowledge of the methods and apparatus used. The operation of the equipment is described, as well as the method of using it for sending messages by wire, mail or radio.

The paper also discusses the practical impossibility of preventing the copying of messages, as by wire tapping, and the relative advantages of various codes and ciphers as regards speed, accuracy and the secrecy of their messages.

Methods of High Quality Recording and Reproducing of Music and Speech Based on Telephone Research, by J. P. Maxfield and H. C. Harrison.[2] The paper deals with an analysis of the general requirements of recording and reproducing sound, with the nature of the inherent limitations where mechanical records are used, and a detailed description of a solution involving, first, the use of electrical equipment for the purposes of recording and, second, the use of mechanical equipment based on electric transmission methods for reproducing.

Probably the most useful feature of the paper is the complete description of the application of electrical transmission theory to mechanical transmission systems. A detailed analysis is made of the analogies between the electrical and the mechanical systems.

[1] A. I. E. E. Journal, Vol. 45, pp. 109-115, Feb., 1926.
[2] A. I. E. E. Journal, Vol. 45, pp. 243-253, Mar., 1926.

Electrical and Photo-Electric Properties of Thin Films of Rubidium on Glass, by Herbert E. Ives and A. L. Johnsrud.[3] Films which spontaneously deposit on glass surfaces in a highly exhausted cell containing rubidium are electrically conducting, and photo-electrically active. A study of the photo-electric properties of a rubidium coated plane glass surface shows the normal and selective effects less well differentiated than for the similar coatings which form on metal plates. A rubidium film formed on the inside of a glass cylinder is found to exhibit, in the dark, a pure ohmic resistance. This decreases under illumination in a manner which appears to be explained as due to the liberation of photo-electrons which under a potential gradient form an added current along the tube.

The Influence of Temperature on the Photo-Electric Effect of the Alkali Metals, by Herbert E. Ives and A. L. Johnsrud.[4] Special cells having a hollow central cathode were immersed in liquid air for an extended period to insure that any gases, if present, were condensed on the outer alkali metal coated walls. The temperature of the cathode was controlled by a stream of evaporating liquid air, whereby all temperatures between + 20 and — 180° C. could be attained and held constant and be measured. In these cells the variation of photo-electric current with temperature in sodium, potassium, and rubidium is continuous, without abrupt changes. The effect is relatively small for sodium, showing hardly at all for blue light or white light, but clearly for yellow light. The behavior of rubidium is similar to that previously reported for potassium.

In a second form of cell, potassium was collected in a deep pool. By slowly cooling the metal from the molten condition, smooth crystalline surfaces were obtained. With these annealed potassium surfaces, the

[3] Astrophysical Journal, Vol. 52, pp. 309-319, Dec., 1925.

[4] Journal of the Optical Society of America & Review of Scientific Instruments, Vol. 11, No. 6, pp. 565-579, Dec., 1925.

variation of photoelectric current with temperature is represented by curves varying systematically in shape with the color of the light, and the effect is far greater than previously reported, amounting, for yellow light, to a variation of 10 to 15 times between room and liquid air temperature. When the surface is roughened curves of the previously reported type are obtained. Small pools give erratic effects, showing changes in opposite directions for different portions of the temperature range. It is concluded that the variation of photoelectric effect is intimately connected with the strains produced in the surface by expansion and contraction with temperature.

Positive Rays in Thermionic Vacuum Tubes, by Herbert E. Ives.[5] Thermionic tubes in which a quantity of alkali metal is present exhibit not only the normal electron current from the heated filament, but a positive current, which at low filament temperatures may be many times larger than the negative current. The electron current is in general reduced by the positive rays, but at higher filament temperatures the reduction of space charge by the positive causes a considerable increase of the current over a limited voltage range. By immersing the tube in liquid air the positive ray effects are almost eliminated, indicating that the alkali metal vapor is the source of the rays, which are probably produced by contact of metal atoms with the hot filament.

A New Directional Receiving System, by H. T. Friis.[6] Reduction of static interference, or to state it more correctly, reduction of the ratio of static to signal, has received, almost since the beginning of the radio art, much serious attention. It is now well known that static disturbances have definite points of origin and that the impulses which are detected at a receiving station have definite directions of propagation. A

[5] Journal of the Franklin Institute, Vol. 201, pp. 47–69, Jan., 1926.

[6] Proceedings of the Institute of Radio Engineers, Vol. 13, No. 6, pp. 685–707 Dec., 1925.

receiving system having no directional selectivity is, therefore, affected by static impulses from all directions and, in spite of many inventions, it has not yet been possible to improve its signal-static ratio except by limiting the frequency band transmitted. A system which, however, is so designed as freely to receive waves arriving from a limited range of directions is susceptible only to static disturbances propagated within that range, and large improvements in signal static ratio have been claimed for different types of directive antenna systems during the past few years.

A directional receiving system for radio telephony in which directional selectivity is obtained by combining the output voltages from two antennas is described in this paper. The main feature of the system is the arrangement for controlling the output voltages of the antennas, so that they may be combined to neutralize each other or to reinforce each other as desired. A double detection (super-heterodyne) receiver is employed and the output voltages, which are combined so as to produce the directional characteristic, are the intermediate frequency currents due to the waves received by the antennas and the beating oscillator currents. The control of these output voltages is effected by operating upon the beating oscillator currents.

High-Power Metallography—Some Recent Developments in Photomicrography and Metallurgical Research, by Francis F. Lucas.[7] The usual conception of high-power metallography seems to be great enlargement, indistinct definition and lack of resolution. Such results, generally, have been classed under the heading "empty magnification" because they have failed to show more detail than has been shown at lower magnifications and with objectives of less resolving ability. Oftentimes the pictures would be unintelligible taken by themselves, but the reason they are recognized at all is because the same structures have been seen and identified by low

[7] Journal of the Franklin Institute, Vol. 201, No. 2, pp. 177–216, Feb., 1926.

or medium-power methods. Such high-power results are like an elastic band which has been stretched unduly. As the band is stretched it becomes more and more attenuated and finally snaps. If the optical image is stretched by enlargement the details of the image become less and less distinct and finally the image breaks down altogether, so that the detail and the background blend together into a hazy outline of what formerly was a sharp image.

High-power metallography as presented in this article consists of so preparing metallurgical specimens that crisp, brilliant images may be obtained and photographed at high powers and of achieving approximately the potential resolving possibilities of splendid objectives.

By improvements in the method of preparing metallurgical specimens and in the technique of manipulating the apparatus, "empty magnification" is no longer synonymous with high-power photomicrography.

It is the object of this contribution to show the application of this new tool for metallurgical research to the study of metal structures which heretofore have not been resolved and the nature of which has led to much speculation and to wide differences of opinion. A clear understanding of the current conceptions of magnification and resolution is essential and a knowledge of the limitations which were regarded for many years as restricting the employment of high powers will prove of value in the interpretation of the results obtained. For this reason a brief discussion follows which not only shows the method of approach in the present development, but indicates the path along which we may work to secure a higher order of resolution. By resolution is meant that property of a lens system which enables it to distinguish or "resolve" as separate and distinct units fine structural details spaced very close together.

Research and Engineering, by E. B. Craft.[8] Research

[8] Address before the Engineers' Club, Phila., Oct. 1925. Engs. and Engg., Jan. 1926, Vol. 43, pp. 11–19.

in industry—which the author mentions is of comparatively recent origin—is defined as the application of methods of systematic and logical deductions to our every-day industrial and technical problems. Such research necessarily is of a highly specialized nature and requires special training. What is equally important, as is pointed out by the author, is the need of properly organizing and directing this group of specialized workers. Since research is a creative process and hence particularly individualistic, one of the important problems in what the author calls "organized research" is the supplying of such an atmosphere that the worker realizes his own welfare and advancement to be adequately cared for in this system of group working. A number of examples of organized research are mentioned: (radio and wire telephony, telephotography, ocean telegraphy, speech and hearing, artificial speech, phonograph recording and reproducing) as apropos of the point in question. The close relationship between engineering and research and the impossibility of the one getting along without the other is made clear. For the worker, there is pointed out the necessity of management and for those in charge the soundness of industrial research as a business proposition. Industrial research far from being a luxury has become a necessity.

Directive Diagrams of Antenna Arrays, by Ronald M. Foster.[9] Two systematic collections of directive amplitude diagrams are shown for arrays of 2 and of 16 identical antennae spaced at equal distances along a straight line with equal phase differences introduced between the currents in adjacent antennae, assuming that each antenna radiates equally in all directions in the plane of the diagram. Three diagrams show the effect of increasing without limit the number of antennae in a given interval. Two models show the effect of distributing the antennae over an area.

[9] Bell System Technical Jr., Vol. 5, April, 1926.

A Static Recorder, by H. T. Friis.[10] This paper discusses different types of apparatus for recording static and also describes a new instrument in which the output of the set is kept constant by automatic control of the amplification, this amplification then being recorded as the relative measure of static. The set makes use of a fluxmeter with zero restoring torque by means of which the rectified output current arising from static interference is integrated over a period of ten seconds. The following five seconds are required to adjust the gain of the amplifier and record the change in gain from an arbitrary level. The gain is recorded in stops of 4 TU which correspond to a power amplification change by approximately a factor of 2.5. A record is shown during which the intensity of static changed by a factor of more than 10,000.

Correction of Data for Errors of Averages Obtained from Small Samples, by W. A. Shewhart.[11] Recent contributions to the theory of statistics make possible the calculation of the error of the average of a small sample—something that cannot be done accurately with customary error theory. Obviously, these contributions are of very general importance, because experimental and engineering sciences alike rest upon averages which in a majority of cases are determined from small samples, and because an average cannot be used to advantage without its probable error being known.

The present paper attempts to show in a simple way why we cannot use customary error theory to calculate the error of the average of a small sample and to show what we should use instead. The points of interest are illustrated with actual data taken for this purpose. The paper closes with applications of the theory to four types of problems involving samples of

[10]Bell System Technical Jr., Vol. 5, April, 1926.

[11]Bell System Technical Jr., Vol. 5, April, 1926.

small size for each of which numerous examples arise in practice. These types are:

1. Determination of error of average.
2. Determination of error of average difference.
3. Determination of most probable value of the root mean square deviation of the universe when only one sample of n pieces has been examined.
4. Determination of most probable value of the root mean square deviation of the universe when several samples of n pieces each have been examined.

The Alkali Metal Photoelectric Cell, by Herbert E. Ives.[12] In the development of the commercial system of picture transmission now in operation over certain of the Bell System lines, one of the initial problems was the choice of a method of transforming the light and shade of the picture to be transmitted into properties of an electric current. There are in general two methods of accomplishing this. The first, which we may term the photo-mechanical method, utilizes some photographic process to produce a mechanical structure, which may be used either to make and break contact, or to produce mechanical movement of some element whose motion produces a variable electric current. The second method consists in the utilization of some light sensitive device which produces or varies an electric current.

An indispensable requirement in the electrical transmission of pictures is speed in conveying the picture from one point to another. The choice of a method of transforming light and shade into an electrical current will therefore, other things being equal, be that method which requires the least time for the transformation. It is on this basis that the photo-mechanical methods were not favorably considered in this development. The preparation of the line or dot structure image, similar to the half tone plate, or the preparation of a photo-relief, are processes which cannot be completed

[12] Bell System Technical Journal, Vol. 5, April, 1926.

in less than one to two hours, and involve a delay which in many cases would seriously detract from the advantages of electrical transmission over other means now available, such as the airplane.

In choosing a photo-sensitive device for this purpose, certain requirements had to be met. The light responsive device should be as nearly as possible instantaneous in its action. The response should also be proportional to the light intensity. These requirements cannot be met by any photo-sensitive devices of the group whose resistance changes under the action of light, such as selenium. The field was therefore limited to the photoelectric cell, of the type in which the effect of light is to release electrons from the surface of the light sensitive element and so permit an electric current to flow in the space between the light sensitive surface and another electrode. Photoelectric cells are considerably less sensitive than the best variable photo-resistances, but while this characteristic would have made them difficult to utilize in the earlier days of efforts at picture transmission, the development of vacuum tube amplifiers admirably fitted for amplifying photo-electric currents has remedied this deficiency. A further requirement, that the light sensitive device should preferably be sensitive to visible radiation, ruled out the use of those sensitive materials sensitive chiefly to infra-red or ultraviolet radiation. All of these requirements pointed to the alkali metal photoelectric cell as developed by the work of Elster and Geitel and others. The paper describes in detail the construction and characteristics of such cells.

Electric Circuit Theory and the Operational Calculus, by John R. Carson.[13] The last of three successive installments comprising an exposition of the fundamentals of electrical circuit theory and the operational calculus.

Development and Application of Loading for Telephone Circuits, by Thomas Shaw and William Fon-

[13] Bell System Technical Journal, Vol. 5, April, 1926.

diller.[14] A review of the art of loading telephone circuits as practised in the United States. The introductory section briefly reviews the theory of coil loading, and summarizes the principal characteristics of the first commercial standard loading coils and loading systems, thereby serving as a background for the description of the various improvements of outstanding importance which have been made in the loading coils and loading systems during the past fifteen years to meet the new or changing requirements in the rapidly advancing communication art.

These major improvements are described in detail under the appropriate headings (1) Phantom Group Loading, (2) Loading for Repeatered Circuits, (3) Incidental Cables in Open Wire Lines, (4) Cross-talk, (5) Telegraphy over Loaded Telephone Circuits, (6) Loading for Exchange Area Cables, and (7) Submarine Cables. The discussion of these various developments sets forth the relations between the loading features and the associated phases of telephone development, such as the cables, repeaters, telegraph working, and carrier telephone and telegraph systems.

The concluding part of the paper gives some general statistics regarding the extent of the commercial application of loading in the United States, and a brief statement indicative of the large economic importance of loading to the telephone using public.

[14] Bell System Technical Journal, Vol. 5, April, 1926.

Notes on Recent Occurrences

FURTHER PROGRESS IN TRANSATLANTIC TELEPHONY

FROM press comments and other sources, it is evident that the general public considers that the opportunity given to press representatives to participate in transoceanic telephone tests on March 7 was an event of great significance in and by itself. Readers of the BELL TELEPHONE QUARTERLY, however, will appreciate, from what has been previously published, that this event was of importance, not as an isolated achievement, but as part of a long series of tests which are directed toward a clearly defined objective.

This objective is to determine the possibilities of providing regular transatlantic telephone service. The present experiments, carried on jointly by the American Telephone and Telegraph Company, the Radio Corporation of America, and the British General Post Office, are a continuation of a series of tests begun more than three years ago. As readers of the QUARTERLY know, the first public announcement of progress in the experiments was that attending the demonstration of January 14, 1923, when officials and engineers of the American Telephone and Telegraph Company talked to London by radio telephone for a period of two hours.

At that time, two-way conversation was impossible, as the British General Post Office was not then equipped with a radio telephone transmitting station for transoceanic purposes. Preparations were, however, under way at that time for the erection of a large radio telegraph station, and after these tests steps were taken by the British postal authorities to add a radio telephone system to this station. This station, located at Rugby, about seventy miles north of London, was put into operation early in the present year. Actual experimentation in two-way transmission was begun soon after this station was opened.

As soon as two-way tests were under way, amateur radio enthusiasts on both sides of the Atlantic began to report that with sets especially adapted for longwave reception, they were listening in on the tests between England and the United States. Such listeners were able to hear both sides of the conversations, although their sets were not sufficiently sensitive to pick up the transmission directly from the more distant transmitting stations. This ability to pick up both sides of the conversation created considerable interest. It is due to the fact that the receiving station and the corresponding transmitting station on either side of the Atlantic are connected by telephone lines to a telephone central office, and are there joined together in such a way as to permit connection to wire telephone circuits. In England, for example, this joining together, as usually carried out, permits part of the current incoming from the British receiving station to pass along the wire circuits into the British transmitting station, thus repeating the transmission from America so that the listener in England hears both sides of the conversation from the British transmitting station. The same conditions hold, of course, in America.

These reports from the amateur listeners increased public interest in the subject of transatlantic telephony, and the press, both in London and New York, requested an authoritative statement as to what was taking place.

It was decided by the officials of the American Telephone and Telegraph Company and the British General Post Office that the best way of insuring that the statements published by the press should give the public a proper picture of the situation was to invite representatives of the New York and London papers and press associations to participate in one of the series of tests that were being carried out each week-end. The test of March 7 was accordingly arranged.

The tests have been described at length in accounts published by daily papers or press associations having

representatives present, and it is hardly necessary to devote space to this phase of the matter in this issue of the QUARTERLY. The informal program continued for four hours, during which some forty American newspaper men talked with an equal number of their colleagues in London. Reception in England and America was clear, without interference from static or other sources and there was a most satisfactory stability in the strength of the received signals. It should be noted, however, that these tests were carried out under conditions as to time of year and time of day which, while they did not represent the very best conditions for transmission, were distinctly favorable. Furthermore, the talkers at the two ends were located directly at the ends of the circuit. Development work must be carried much beyond the point represented by these tests to permit an uninterrupted, all-the-year telephone service between the public telephone systems of America and Great Britain.

The table given below is of interest in this connection:

LONDON	*Afternoon* 12 M.–6 P.M.	*Evening* 6 P.M.–12 P.M.	*Early Morning* 12 P.M.–6 A.M.	*Forenoon* 6 A.M.–12 M
NEW YORK	*Forenoon* 7 A.M.–1 P.M.	*Afternoon* 1 P.M.–7 P.M.	*Evening* 7 P.M.–1 A.M.	*Early Morning* 1 A.M.–7 A.M.
Commercial Importance	Most Important	Second in Importance	Of Least Importance	
Transmission	Intermediate	Poorest	Intermediate	Best

In this table it will be noted that the day in London has been divided into four parts, which have been called "afternoon," "evening," "early morning" and "forenoon," corresponding respectively to the periods from noon to 6 P.M., 6 P.M. to midnight, midnight to 6 A.M., and 6 A.M. to noon. The time in America lags five hours behind that in England. In the table, under each of the periods as noted for London, is indicated the corresponding parts of the day in New York. The time difference between the two countries is such that the

same names of "forenoon," "afternoon," "evening" and "early morning" can be assigned, as indicated in the table, to the periods in New York.

Referring to the table, it will be noted that the period designated as "best" from the transmission standpoint is during the "forenoon" in London and the corresponding "early morning" in New York. Evidently this, however, is very inconvenient to a New York subscriber.

The time of day of most commercial importance is evidently that corresponding to "afternoon" in London and "forenoon" in New York. This period includes the overlapping business day, and is the time during which the tests for the newspapers were carried out. From the transmission standpoint this period is marked "intermediate" in the table, since it is neither the best nor the worst. The objective which is now in mind in the transoceanic work is to bring about sufficient improvement in conditions to permit transmission to be given during this period throughout the year. If this can be done, it will mean, of course, that the period previously mentioned as "best" from the transmission standpoint will also be available throughout the year, and likewise another period corresponding to "early morning" in London and "evening" in New York, also labeled in the table as "intermediate" in transmission, will in general permit satisfactory transmission.

The remaining period, corresponding to "evening" in London and "afternoon" in New York is evidently second in commercial importance, as it includes times of day when subscribers in both countries are normally awake. It is, however, the poorest from the transmission standpoint, and very radical developments, a long way beyond anything so far accomplished, must be made before service could be given continuously during this period during the summer months.

In addition to the transmission problems which are suggested only in part by the above discussion, there

are serious operating and commercial problems which must be solved before it will be possible to join together the telephone systems in America and in Great Britain. Each telephone connection, will involve not only the radio link but also the building up of wire circuits at the two ends. The operating practices and the tariff structures in the two countries have, of course, been developed to meet quite different conditions. The operating difficulties will be further increased by the fact that the radio link does not furnish from the transmission or the signaling standpoint the stability and reliability of the usual wire circuits.

In view of all the above, we can at this time, therefore, report only the important progress which has been made, and make little useful prediction as to what it may later be found possible to do from the standpoint of commercial service.

THE TELEPHONE'S FIFTIETH BIRTHDAY

IN recognition of the 50th birthday of the telephone on March 10, 1926, many congratulatory communications were received at the headquarters of the American Telephone and Telegraph Company. The following telegrams were of particular interest:

FT. MYERS, FLA., March 10, 1926.

WALTER S. GIFFORD, *President*,
American Telephone and Telegraph Company,
195 Broadway, New York.

Founded on science and great business sagacity the march of the telephone has been steadily onward and upward to the stupendous success of the present day. The end is not yet. I heartily congratulate the company and its personnel on the celebration of its Golden Jubilee.

THOS. A. EDISON.

NEW YORK, March 10.

THOMAS A. EDISON,
Fort Myers, Florida.

We greatly appreciate your kind message of congratulation. Your unique position in the field of science and invention gives to your generous commendation of telephone progress greater weight than could come from any other living American, and encourages us to accept the grave responsibilities of future development and growth.

WALTER S. GIFFORD.

March 10, 1926.

MR. THOMAS A. WATSON,
Passagrille, Florida.

We remember today with feelings of deep appreciation that on March 10, 1876, there was spoken into the telephone the first complete sentence ever transmitted by electricity. It was Alexander Graham Bell who spoke these words and it was you who heard them. Bell was the first to speak through the telephone and you were the first to hear. The instruments were invented by Bell but they were made under his direction by you, with your own hands, and you ran the first telephone wire over which these words were carried. This historic sentence was spoken in a room at 5 Exeter Place in Boston. The wire transmitting these words was less than fifty feet in length extending only to another room in the same building. On that day the personnel of the Bell System consisted of but two, Dr. Bell and yourself. Today, March 10, 1926, hundreds of thousands of members of the Bell System, including our connecting companies, throughout the United States are celebrating this historic achievement of which you are now the only survivor. From their hearts there goes out to you today the words of Bell when he spoke the historic first sentence, "Mr. Watson, come here; I want you." On

behalf of the men and women of the Bell System I send you on this, the fiftieth anniversary of the telephone, congratulations and best wishes.

W. S. GIFFORD.

ST. PETERSBURG, FLA., March 10, 1926.

W. S. GIFFORD, *President*,
American Telephone and Telegraph Co.,
New York, N. Y.

I am very grateful to you for your kind telegram of today and thankful that I was chosen by the fates to be the associate of Alexander Graham Bell in his wonderful work and happy that I may call myself one of the splendid body of men and women who have made of Bell's invention an instrument of such tremendous service to mankind.

THOMAS A. WATSON.

THE ANNUAL MEETING

AT the Annual Meeting of the stockholders of the American Telephone and Telegraph Company, which was held at the headquarters building at 195 Broadway, New York, on March 30, the same directors were reelected, except that Mr. Daniel Willard was elected in the place of Mr. W. W. McClench, resigned. The transactions of the past year were approved.

There were 5,947,372 shares voted by proxy or in person, which represented 64 per cent. of the outstanding stock.

Organization Changes

Southwestern Bell Telephone Company

A. B. Elias elected First Vice-President

Entered the employ of the Bell System as a cable tester, New York Telephone Company, March, 1900; Foreman, September, 1900; Supervising Foreman, July, 1907; General Construction Foreman, January, 1908; Division Plant Superintendent, Syracuse, N. Y., March, 1911; General Superintendent of Plant, Southwestern Bell Telephone Company, Dallas, Tex., January, 1913; General Plant Superintendent, December, 1915; General Manager, Dallas, June, 1917; Second Vice-President, St. Louis, Mo., April, 1919; Vice-President, September, 1919.

J. K. Wass elected Vice-President

Entered the employ of the Bell System in the auditing department of the New England Telephone and Telegraph Company, Boston, Mass., 1886; Auditor, Bell Telephone Company of Missouri, St. Louis, Mo., 1903; General Auditor, Southwestern Bell Telephone Company, March, 1912; Vice-President, Kansas Telephone Company, April, 1925.

W. J. O'Connor elected Vice-President

Entered the employ of the Bell System as Publicity Agent, Southwestern Bell Telephone Company, St. Louis, July, 1917; General Publicity Agent, September 1, 1919; Assistant to President, September 20, 1919.

E. F. Carter elected Vice-President

Entered the employ of the Bell System as an inspector, Bell Telephone Company of Missouri, St. Louis, Mo., June, 1900; Solicitor of Right-of-Way, June, 1901;

General Foreman, October, 1901; Canvassing Agent, American Telephone and Telegraph Company, St. Louis, 1905; Special Clerk, Bell Telephone Company of Missouri, November, 1907; Contract Agent, January, 1908; Commercial Manager, July, 1910; Commercial Engineer, Southwestern Bell Telephone Company, October, 1913; General Manager, Topeka, Kans., October, 1917; General Manager, Dallas, Tex., April, 1919; General Commercial Manager, St. Louis, Mo., April, 1921.